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PROCEEDINGS OF THE TRANSPORTATION DEVELOPMENT CENTRE RAILWAY ENERGY SEMINAR

TRANSPORTATION DEVELOPMENT CENTRE
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17. Abstract

The proceedings from the Transportation Development Centre sponsored railway energy seminar are presented in this document. Topics include railway energy conservation activities, alternative rail diesel fuels, energy efficient locomotive developments, railway electrification and the federal energy R&D program. A summary of the discussion which took place at the end of the seminar is also given.

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17 Résumé

Ce document présente le recueil des exposés du séminaire parrainé par le Centre de développement des transports, traitant de l'énergie des chemins de fer.

La conservation de l'énergie des chemins de fer, l'utilisation de carburants de substitution pour locomotives diesel, les développements de locomotives éfficaces au niveau énergétique, l'électrification des voie ferrées et le programme féderal de recherche et de développement sur l'énergie ne sont que quelques-uns des sujets traités dans ce recueil. Un résumé des discussions ayant eu lieu à la fin du séminaire est également inclu.

18 Mots-clés	19 Diffusion
Chemins de fer, conservation de l'energie, carburants de substitution pour locomotive diesel, locomotive, electrification, recherche	Le CDT dispose d'un nombre limité

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FOREWORD

The seminar was organized by the Transportation Development Centre (TDC) of Transport Canada in order to provide a forum for the exchange of information within the railway industry and to acquaint concerned federal government personnel with current and planned future industry efforts in this important area of railway operations. R.S. Nishizaki was the TDC project officer responsible for its implementation. Assistance was provided by R.G. Maughan, a consultant retained to develop the program.

Chaired by Mr. Peter Eggleton, Executive Director of TDC, the day-long seminar covered the principal ongoing activities of railway operators and locomotive manufacturers directed towards reducing the impact of escalating cost of petroleum fuel. To round out the picture, Dr. W.F. Johnson, Chief, Energy Research and Development, Transport Canada, presented a summary of the federal Energy R&D Program, with emphasis on those parts of the program managed by Transport Canada.

In his opening remarks, Mr. Eggleton noted that the sponsorship of technical seminars has been, and continues to be, an important element of TDC's role, and that the large attendance, divided almost equally between industry and government, attested to the interest in this subject.

TDC expresses its thanks to all the seminar participants and, in particular, to the speakers, whose papers are reprinted here. As a result of the favorable response to this seminar, TDC looks forward to sponsoring another meeting at the first opportune moment.

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DISCUSSION

REGISTRATION LIST

ON THE ENERGY QUESTION AT CN RAILWAYS

William H. Cyr
Corporate Director
Energy Resource Planning
Canadian National

THE ENERGY QUESTION AT CN RAILWAYS

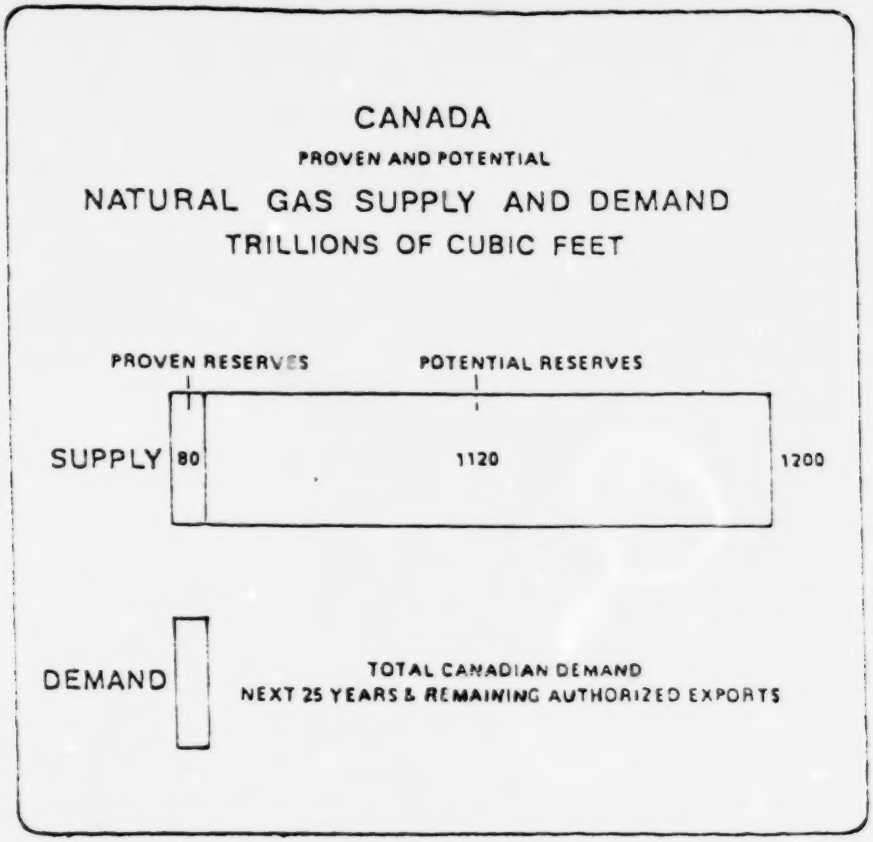
Before considering the question of the dynamics of train operation as it is related to fuel consumption it may be well to describe first some of the views of CN management on the subject of energy and how these views were reached. It would also be of interest to identify some of the many areas where a great deal of thought and effort is being expended at all levels of the company organization.

In 1980 it became clear to CN Railways' executive that the railway's policy regarding energy questions should be defined in broad general terms to provide guidance to the various railway departments regarding the directions these should take vis à vis energy. On the surface it would seem that the policy could be very simple and could be stated in an apostolic manner by simply saying to all and sundry "go out and conserve energy". Unfortunately it is not this simple. While conservation is an important part of the policy it does not address questions such as the cost of fuel, electrification or whether the output from CN's oil wells should be used as economic leverage in the purchase of fuel oil at a less expensive price.

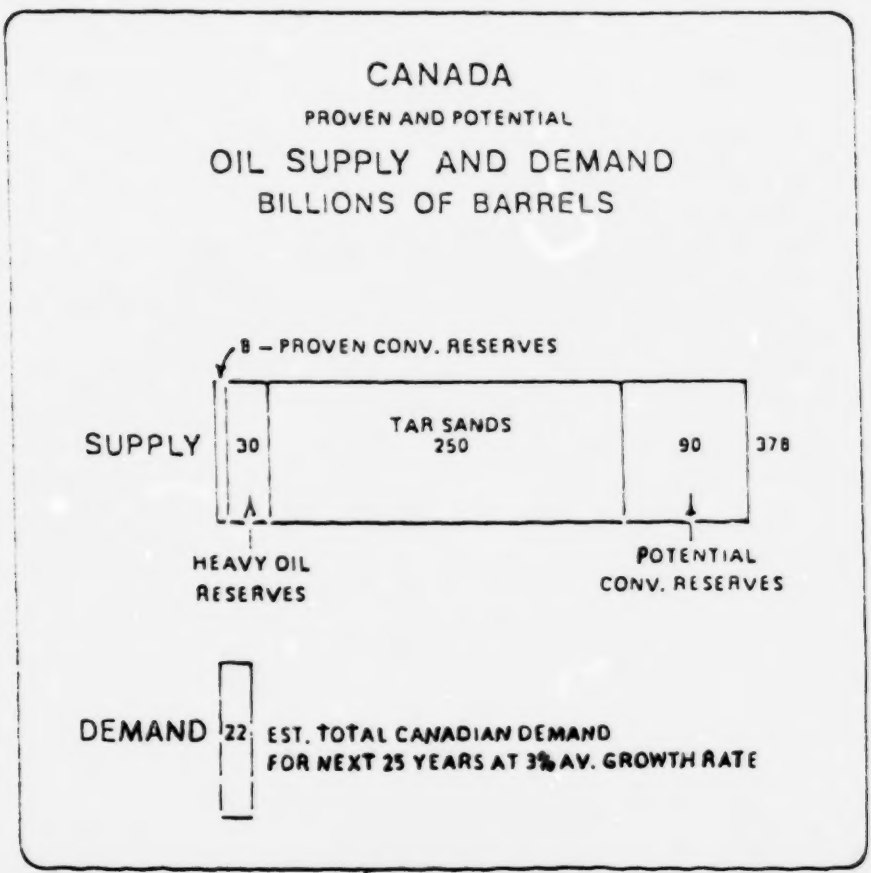
It was accordingly decided that the Policy Committee on Energy would be formed of corporate officers who were charged with the responsibility of recommending policy regarding matters of energy to the executive.

There were two main concerns regarding energy. The first concern was that of supply and this was not only a question of importance to CN Management, but had been a national question and gave rise to moves by the Federal Government such as the Energy Supplies Emergency Act administered by the Energy Supplies Allocation Board in 1979. The second concern was a financial one, and this was also a national question eventually leading to the National Energy Plan of 1981. Between 1980 and 1981 the increase in the fuel bill for diesel locomotive fuel at CN was of the order of $85M. As far as supply is concerned when CN management looked into the question it became apparent that the supply of fuel was not likely to run out, there were many sources of information leading to this conclusion. This can be illustrated graphically in the following two slides. These are just an example of how the the situation was envisaged at that time by a major oil supplier. The first slide shows the supply and demand for natural gas and we see from this slide that Canada has a known supply of natural gas which will last for 375 years. Slide No. 2 depicts the oil supply and demand, as you see Canada has 430 years of supply in this area at present rates of consumption even if no additional oil is discovered. In spite of the fact, however, that supply did not seem to be a problem, the question of cost was still of deep concern. This was particularly true of fuel for locomotives which was reaching to 15% of the total operating costs of the railway.

SLIDE 1



SLIDE 2



While the cost of fuel oil loomed above any other concern it was decided that a concerted effort would be made by all departments to reduce the cost of energy either by modifying operating mothods, or by taking steps leading to conservation. As a result of this policy a great many people have worked very hard and have achieved a great deal in many different fields. I will list a few of these:

- installation of solar heating equipment
- modification of heating plants
- installation of more energy efficient furnaces
- monitoring and adjusting of electrical consumption
- adjustment of ventilation in buildings
- reduction of the speed of ships operated by CN Marine
- use of less expensive fuels

The real estate holdings of the railway are impressive insofar as buildings are concerned, 692 of these being multi-storey with needs for heating and lighting. When these buildings were built the designers were not particularly concerned about energy conservation because energy was much less expensive than it is now, and a great deal has yet to be done to rectify this situation. Many energy audits have been carried out and many buildings have been modified in accordance with the findings of these audits.

The biggest single energy cost lies with diesel locomotive fuel. Electrification seems to have a universal appeal for everyone who is seeking to deal with an ever growing fuel bill. This meant

that there might be economic justification for electrification of the railway, although electrification could not be undertaken without the investment of very large sums of capital. No definite conclusion has yet been reached as to whether the railways should electrify or not. This matter is under study. In any case it cannot be a short term solution to the fuel problem. Of particular interest at the present time is the electrification of the British Columbia Railway into the coal fields from Tumbler Ridge Coal Mine site to Anzac, a distance of 132 km. In any case, electrification cannot produce immediate relief from the use of fuel oil and the problem still remains and will remain for several years even with the most optimistic outlook for eventual electrification.

Several steps have been taken to reduce the diesel fuel cost problem. These steps such as shutting down locomotives when they are not in use, installing more reliable fuel dispensing nozzles, using a less expensive fuel by modifying our fuel specifications, experimenting with residual blends to permit the burning of a heavier fuel, etc. are very effective. Don Jackson will enlarge on these developments later today.

Very important gains can be made in the area of train handling techniques where some of the biggest and quickest savings can be realized. At the present time train operators usually try to operate at subdivision speeds irrespective of the delays they may encounter later at meets, etc. Railways in general on the North American continent have had the means to contact the train and control speeds through dispatching offices since the adoption

of train to way-side radio. And some of this is done now on the British Columbia Railway.

Aside from this we have the situation where train operators, even without assistance from the dispatcher, can improve fuel consumption in many ways. It is estimated that fuel consumption can be reduced by 10% with the specialized training of train crews. This, in fact, is being done at CN and on many other North American Railways.

It is interesting to look at the dynamics of trains moving on rails in order to get some idea of the magnitude of the forces involved and how this influences the fuel consumed. This can and has been demonstrated in many different ways, but it is very well illustrated if one looks at it from the point of view of Newton's Second Law of Motion beginning with the famous equation $F = MA$ and the manipulation of that equation to where change in force between point A and B is expressed by change in the Kinetic energy between these two points. The next three slides illustrate how important a source of fuel savings this can be.

Slide 1. Assumptions regarding the weight of an empty hopper car.

2. KE calculation for translation and rotation of wheels and axles.

3. Fuel consumption measured on actual trains.

NEWTON'S SECOND LAW OF MOTION

$$F = M_A = \frac{W}{G} A$$

$$A = \frac{DV}{DS} \times \frac{DS}{DT} = V \frac{DV}{DS}$$

$$\therefore F = MV \frac{DV}{DS}$$

$$F_{DS} = MV_{DV}$$

WITH CHANGE IN SPEED A TO SPEED B CHANGE IN KINETIC ENERGY (KE)

$$\int_B^A F_{DS} = \int_B^A MV_{DV}$$

$$KE = \frac{1}{2} MV_A^2 - \frac{1}{2} MV_B^2 \quad \text{TRANSLATION}$$

$$KE = \frac{1}{2} I_W W_A^2 - \frac{1}{2} I_W W_B^2 \quad \text{ROTATION - WHEELS \& AXLES}$$

WHERE I = MASS MOMENT OF INERTIA

W = ANGULAR VELOCITY

Δ KE Vs Δ V

SAY COVERED HOPPER CAR WEIGHT = 60,000 LBS.

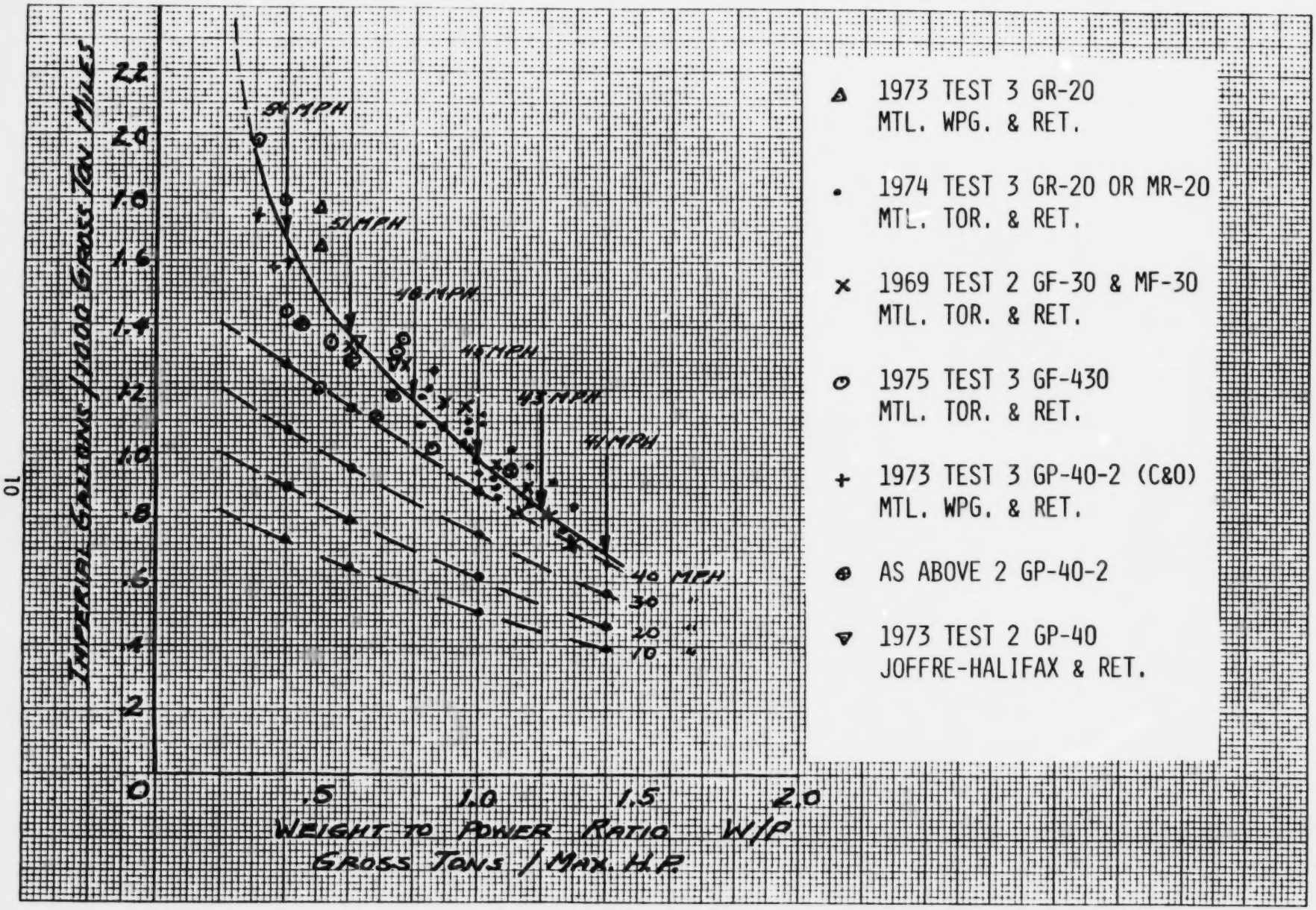
AT 60 M.P.H. KE TRANSLATION
AND WHEEL & AXLE ROTATION = 7,751,626 FOOT LBS.

ASSUME 10% SPEED REDUCTION TO 54 M.P.H.

Δ KE TRANSLATION & ROTATION = 6,279,249 FOOT LBS.

Δ KE = 1,472,385 FOOT LBS.

19%


IMPERIAL GALLONS / 1000 GROSS TON MILES
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
54 MPH
51 MPH
48 MPH
45 MPH
43 MPH
41 MPH
40 MPH
30 "
20 "
10 "
.5
1.0
1.5
2.0
WEIGHT TO POWER RATIO W/P
GROSS TONS / MAX. H.P.
▲ 1973 TEST 3 GR-20
MTL. WPG. & RET.
• 1974 TEST 3 GR-20 OR MR-20
MTL. TOR. & RET.
× 1969 TEST 2 GF-30 & MF-30
MTL. TOR. & RET.
○ 1975 TEST 3 GF-430
MTL. TOR. & RET.
+ 1973 TEST 3 GP-40-2 (C&O)
MTL. WPG. & RET.
⊕ AS ABOVE 2 GP-40-2
▽ 1973 TEST 2 GP-40
JOFFRE-HALIFAX & RET.

The big question that remains now is how railways are going to capitalize on this and so operate trains that the greatest possible benefit is realized. It is generally agreed that while large gains can be achieved by intelligent and careful locomotive operation, the ultimate in fuel economy will only be reached with computer assisted dispatching. This now exists in some airlines in Canada. Unfortunately, in a railroad application the system becomes very complicated. The complexities stem from geographical differences that improve different methods of operation from one end of the country to the other even on the same railway. When different railways are involved this problem becomes still more complicated. In spite of these difficulties standarization is essential.

It is very likely that the railways will proceed with this in a series of evaluationary steps which will produce improvements in fuel economy as they are instituted with the ultimate results being realized only several years from now.

Some railways such as the Southern Pacific have made the decision to get immediate results and have imposed a speed limit on all non-expedited trains of 45 mph. This was a courageous decision for a railroad management that prided itself on the speed of S.P. trains across the desert.

ENERGY CONSERVATION AT CP RAIL - A GLANCE BACK AND A LOOK AHEAD

Donald R. Hollm
Director Energy Utilization
Canadian Pacific Rail

ENERGY CONSERVATION AT CP RAIL
A GLANCE BACK AND A LOOK FORWARD
****

I'd like to thank you for inviting me to be with you today to participate in describing what Canada is doing in Railway Energy Conservation. Having recently attended a somewhat similar seminar in the United States, I was very pleased to discover that Canada is a leader in this area. So, I hope you not only share my interest in what is presented today, but also my pride as one of the participants in these accomplishments.

I will address several areas today, including past accomplishments, locomotive add-on devices, fuel security and buildings. But, with all the interesting things we are doing now and have planned for the near future, I'll only glance at the past and then look forward at where we're headed.

In focusing on where we are headed, I should note that many items are still under development and not yet finalized. Keeping this is mind, I'd like to provide you with an idea of the directions in which we are headed as well as some insights into the problems we're facing.

First, the Past. As we are only glancing at it, I'll just touch on two of our more noted past accomplishments, reduced idling and improved fueling.

Reduced idling is fairly straight forward. An idling locomotive consumes fuel, 3-1/2 - 5 gallons per hour. Shut it down and it won't. But, there are some constraints. Highly turbo-charged engines don't start well below 40-50 degrees F ambient temperatures. And, even if they did, we still have to provide winter freeze protection for the cooling system which doesn't use anti-freeze. When its above 50 degrees F and when the loco won't be used within an hour, we shut them down,. This saves us above 1.4 million gallons of fuel per year. The same idea of reduced idling is applied to reefer cars and caboose generators.

The second area where we have made major savings is through improved fueling practices. Thats the Public Relations way of saying we spill less fuel when fueling the locomotives because of

improvements to the automatic shut off nozzles. The spilled fuel is collected and burned in boilers, so it isn't lost, but we consider this a wasteful use of a premium product. In 1976, we spilled about 1.3% of total fuel. This has now been reduced to 0.17%, saving over 2 million gallons per year. And we're working on further reductions.

How was this done? In several ways.

One problem was related to the level of fuel in the tank when it was full. When it was filled on level track, no problem. But, locomotive movements, uneven track or expansion of fuel in the summer heat caused fuel to run out the top. There was also a problem of fuel surging out the vent, as the nozzle automatically shut off. Both of these problems were rectified by lowering the "full" level in the tank.

Another problem was failure of the fuel nozzle to shut off once the tank was full. The nozzle senses a full tank by sucking air through a shut off tube inserted in the tank. As long as the fuel level is below the end of the tube, nothing happens. As the tank fills and the fuel level rises, covering the end of the tube, a vacuum is created which causes the nozzle to shut off. But, if any air leaks occur at coupling joints or in the shut off tube, no vacuum forms and the fuel keeps flowing. Upgraded "O" ring maintenance, component testing and a redesigned shut off tube have solved this problem.

Thats the glance back. Now the look forward. I'll start with Locomotive Add On Devices.

"Add on this device and cut your fuel bill by 15-20% with a 3-month payback". Believe me, when you spend $250-$300 Million/Year for fuel, thats tempting. What is it? Its one of the many Godfather offers that we regularly receive for add on devices. The problem is, they aren't usually that straight forward. I'd like to give you some insight into this area by citing one example, "SET-A-SPEED".

This add on device is a cruise control for trains which also idles trailing locomotives to keep the other units in a higher notch position, instead of having all locomotives run at the less fuel efficient lower notches.

I was quoted 15-20% savings on a road with over 6 HP/Ton ratios. We run considerably lower HP/Ton ratios, so we expected somewhat lower savings, but not the 2% increase we found on a simulated coal train run. Thats right, an increase.

But the idea makes sense, units are more efficient when in higher notches, as this slide shows. It says that you can save fuel by optimizing time in the higher notches. Two units at half power will use more fuel than one at full power because of the lower specific fuel consumption at the higher notch.

This slide gives you an example. Using 5, SD40-2's to generate 7,000 HP, I've listed two possible configurations. In the first case, all are in Notch 5. In the second case, 2-1/3 locomotives are in Notch 8 while 2-2/3 are at idle. Actually, one alternates 33% at Notch 8 and 66% at idle. As you can see, optimizing Notch 8 operation saves fuel in this case.

Good idea, but what happened in our coal train simulation?

Look at this slide. It tabulates the specific fuel consumption of several types of locomotives by notch. Note that the C-424 and M 636 are most efficient in Notch 8. But look at the SD 40, SD40-2 and MLW 1800's. They are all more efficient in Notch 7. In fact, the 1980 SD40-2 is almost 7% more efficient in Notch 7 than 8. If a consist of SD40-2's was running in Notch 7, would you save fuel with SET-A-SPEED by idling some and running the rest in Notch 8? No. Quite the contrary. As this slide shows, you'd use more. You want to optimize your time in the most fuel efficient throttle position for the particular locomotive you are using.

No problem, if you use SD40-2's, optimize Notch 7. If you use M636's, optimize Notch 8.

But, what if you have a mixed consist of SD40's and SD40-2's. You could save fuel by optimizing Notch 7, but you could save more by shutting down the less efficient SD40's, even if it meant running the dash 2's at Notch 8.

These are steady state conditions. Things get more complicated when

you add differing power requirements throughout a specific run, operating constraints required for safe train handling and efficiency variations with speed, just to name a few.

Set-A-Speed also impacts fueling logistics due to the uneven fuel use between units. Units running at full power will run out of fuel faster than the units running at lower throttle settings.

There are many other considerations, but I think you get the point. Add on devices are not always as "simple add on's" as is sometimes suggested.

Having listed some of the pitfalls, I should note that they haven't stopped us.

We're minimizing the variables by looking at unit trains, and running simulations to find the optimum operation and ballpark potential savings. If justified, we'll test them on site. The third topic is fuel security. I'll spare you pictures of fences, locks and lights and concentrate on our computerized fuel management system.

An entire seminar could be devoted to describing the details of operation of this system but time constraints will save you that pain. What I'll do is touch on:

- Why we are developing this system;
- Some of the basic guidelines of the design;
- A brief look at fueling operations using this system;

AND then take a look at

- Some sample screens to describe what we hope to receive for our efforts and money.

Our $250-$300 million fuel bill has naturally led us to ask ourselves a number of questions.

How much fuel do you have on hand, right now?

Do you know exactly where your fuel is being used?

Are you being billed for more fuel than you receive?

Do you have a leaking tank?

Is fuel being stolen?

Do you return partially filled fuel tank cars?

Is locomotive fuel used for heating? How much?

We weren't fully happy with all the answers to these questions and believed that we had outgrown the present manual system. Over 1,000 fuel transactions per day and increased fuel costs dictated that we develop a computerized fuel management system.

The complexities of developing and installing a complete system encouraged us to start with only the core of the system. This core would receive issue, receipt and inventory information and provide basic site and accounting information. After proofing at four pilot locations, additional functions would be added and other locations brought on stream. This is the stage we are at now.

A little background first. CP Rail receives fuel by one of these means; from a tank car, truck, pipeline or ship into our storage tanks or directly from a truck into the locomotive or equipment.

And, it is issued by one of these methods. From a storage tank or truck into the locomotive, equipment or facility or from a storage tank to a tank car for transfer to another location. This last issue type is not a normal part of our operation, but could become so in the event of a fuel shortage.

I'll go quickly through one sample type of receipt and issue operation and then we'll look through some of the screens.

First, the sample receipt operation, in this case, a truck to tank delivery.

Fuel is received through a totalized temperature compensated printing meter.

The truck driver inserts a receipt meter ticket into the printer, zeros the meter, unloads the fuel, and recranks the meter, printing the literage, meter and transaction identification. Then, he attaches the truck meter ticket to the CP ticket and puts it in the Bunker Box.

Now for an issue. The issue ticket is inserted in the printer; which is cranked to zero, the unit is fueled, and the meter cranked to record the fuel quantity and other information on the ticket.

The fuel jockey fills in information such as unit number, CP, VIA, or foreign road, etc. and puts the ticket in the Bunker Box.

At the end of each shift or stock take, both the issue and receipt tickets are collected and brought to the office where additional information may be added and where they are input to the computer.

Now, I'll go through a few screens to give you an idea of the input and output but I must apologize for having to use dummy screens. We had problems blanking out information which identified the performance of specific suppliers at each location.

To input an issue ticket, we call up the fuel issued screen where we can input the issue ticket information. We could also check a past entry with this screen or make a correction.

The same applies to the receipt screen. Note that the percentage difference between the CP meter and supplier invoice quantity is calculated by the computer and listed in the bottom right corner. One of the systems' add on functions is an accounting link to catch discrepancies between received, ticketed or invoiced quantities of fuel. This ensures we get what we paid for.

The stock take is used to correct the computer calculated inventory level back to actual. This eliminates the effects of

theft, leaks, lost or late tickets, etc. which can cause errors in the computer inventory level.

The location fuel status screen provides all the inventory information for each fueling location. Each location can only access its own status but, of course, all are accessible to System.

On the upper left, you see the fuel on hand in the storage tank and also in tank cars already at the location, but not yet unloaded. The total of these two is the total fuel on hand. You also have the quantity of fuel in transit to this location by tank car and the total of all three.

The fuel quantities are listed in both litres as well as days consumption based on average consumption. We know that some locations don't have smooth averages, but for the majority of locations, the number of days fuel supply gives a good quick indication of your fuel status.

Note that the "In Storage" is highlighed. This is because the fuel "In Storage" has fallen below the safe operating limit set for that location. The safe limit can be set in either average days consumption or in litres. If the "In Storage" and "In Tank Cars" combined was below the safe limit, they would both be highlighed and if the addition of "In Transit" also fell short of the safe limit, then all three would be highlighed. This progressive highlighting gives a quick indication of the status of each location, and, as you'll see later, it'll allow a quick identification of the trouble spots out of a system-wide summary of information.

The on-hand surplus is the amount of fuel on hand over the safe limit. The primary purpose of this number is as a measure of sources of excess fuel which can be transferred to other locations during a shortage. It is also an indicator of how much time the location has before it gets tight on fuel.

On the upper right, the stock take discrepancy is listed. The discrepancy is a measure of the difference between actual and computer calculated inventory levels. This discrepancy allows a quick check as to how safely you can rely on the computer calculated fuel on hand. If you previously had

a 100,000 litre discrepancy build-up in one week and you have not had a stock take in the last week, you would be very nervous about relying on 100,000 litre calculated fuel on hand. That's an extreme that we hope we never have, but it does illustrate the "safety net" effect.

This screen summarizes the location status screens for the entire system. Through the highlights you can quickly find trouble spots for further study. An identified problem location would then be investigated by bringing up the previous location fuel status screen for that location.

This screen also identifies the on-hand surplus of fuel available for shifting during an emergency.

That covers the highlights of our fuel management system.

Now, I'll look at the last topic, Buildings.

Energy costs other than locomotive fuel comprise less than 15% of our total energy bill. And, of that portion, only about a quarter is used to heat buildings. While that is a small part of the total bill, it still offers substantial dollar savings with a very respectable rate of return. Today I'll present several of our energy conserving accomplishments in the building area along with some of the insights they have provided us. However, first, let's take a look at what we are up against.

The majority of our buildings were constructed using designs that addressed the problems of the early 1900's. Skylights and large window areas helped offset low lighting levels. Buildings were, for all practical purposes, uninsulated.

Most station buildings were also uninsulated and utilized hot water radiator systems controlled by periodic manual adjustment of radiator valves. Time corroded open the radiator valves which resulted in windows being opened or closed to control temperatures. This results in heating requirements of approximately 75-150 KWH/Year per square foot of floor area.

Let me put that in perspective. That is 75-150 compared to an average house at 30, or the latest energy efficient house at 4 to

8. Or, put another way, if you had a 1,500 square foot electrically heated house using 150 KW Hr./Square Foot, it would cost you $9,000/Year to heat it at 4 cents per kilowatt hour.

As one would expect, the old shops consumed more.

While these consumptions are high, they are not unusual for this type of industrial building. Would there be more "bang for the buck" in an industrial energy program than a home plan? Or, at the risk of groans from electrification advocates, would the return on investment, as well as the off oil effects of a dollar invested in industrial conservation, exceed those of electrification.

Now that the plug for Industrial Energy Conservation is in, let's look at some of the things we've done without such support.

At the Saint John, N.B. station, we removed the steam to the auxiliary and replaced this protection with electric heating elements. We replaced the remaining steam boiler, now grossly oversized, with a properly sized hot water boiler, and added temperature controls.

Look at the results. The boilers and temperature controls offered a combined payback of less than three years, but the startling results is the reduction in consumption.

The boiler and controls cut the building consumption 70% while improving working conditions.

Another way to conserve is to take this, and do this.
You can stop there and save the most or replace it with this.

You save several ways. The old inefficient shop consumed 151 KW/Sq. Ft. The new shop consumes only 45 KW/Sq. Ft.; 70% less, while providing improved worker comfort. Additionally, the new shop is less than half the size of the old shop while providing improved worker efficiency.

After trading off the higher cost per BTU of the propane which replaced some of the Bunker C, we ended up saving over $100,000. per year on heating costs.

I've used this to derive a dollar saving per square foot of new building for this project. A very unscientific number and one specific to each project but a good indicator, none the less, of the general potential of justifying new buildings solely on energy savings. Shops we looked at tend to lie in this area of $5/Square Foot while replacement of stations tended around $3/Square Foot. As I said, very unscientific, but it does show that with the present incentives, New Replacement Facilities will be built based mainly on operating requirements with energy savings only as a Bonus.

One of the nice things of replacing or building new structures is that we have the opportunity to begin with a clean slate. We want to be sure that we don't regret the design of our new building in 5 years, or for the remaining 50-70 years of their life.

One example of this approach is our new Coalhurst Yard Office. For those who like to look at girders.

And for the conceptual minded.

The aim of this building design is to consume 30% of the energy that a similar conventional building would consume. Except for added insulation, all energy design modificications were aimed at equalling or reducing costs relative to a conventional building.

These are some of its features.

A water circulating system coupled to zone heat pumps distributes heat or cooling. A new type of heating system eliminates the conventional paradoxical method of adding heat to one portion of the building while air conditioning another. Only net building heating or cooling is made up with this system. Increased system costs are offset by decreased ducting and control costs.

Another new building with a message is our new Coquitlam Diesel Shop. It incorporates the state of the art ideas of using a minimum of windows, high pressure sodium lights, R-20 roof and wall insulation, and radiant heat but the interesting part is our approach to ventilation. During the design stage, the Engineering and Mechanical Departments looked at their ventilation options in building this shop. If we

didn't operate engines in the shop, we could provide minimal ventilation while meeting the standards. The other two options were to allow locomotives to run in the shop and ventilate to meet either the old 10 PPM nitrogen dioxide standard or to the new government standard of 5 PPM.

The interesting part is the additional cost of allowing units to idle in the shop. And note that these are 1980 building and energy costs. It would cost over $567,000, up front, for ventilation equipment and space, plus, over $162,000 per year in added heating costs to run units in the shop. Was it worth the cost?

In this case, we didn't think so. But, operating constraints do not always allow this option. And there's a message there. The 5 PPM nitrogen dioxide standard would have cost $247,000 more than the old 10 PPM standard plus $70,000 per year more in energy costs. Thats money that could be spent saving energy or improving Canada's productivity. Help comes in more way than handouts.

Thank you.

D.R. Hollm
Director, Energy Utilization

ALBERTA CRUDES AND TAR SANDS PRODUCTS AS LOCOMOTIVE FUELS-HISTORICAL REVIEW

Dr. R. B. Whyte
Head, Fuels and Lubricants Laboratory
National Research Council, Ottawa

SELECTED PROPERTIES OF FUELS

	Typical Alberta Crudes	Distillate Fuel Spec.
Specific Gravity 60°F	0.815-0.860	0.880 max.
Viscosity, cSt at 100°F	2.9-6.5	33 SUS min.
Flash point, °F	-50	125 min.
Reid vapour pressure, psi	4-12	<1
Distillation, °F		
10% recovery	212	460 max.
50% "	525	535 max.
90% "	575 (40mm Hg)	675 max.
Residue %	23	-
Ash, % wt	0.002-0.011	Nil
Corrosion, Cu strip	1A-4C	1A max.
Cetane number	37-46	45 min.
Pour point, °F	-10 to +32	as reg'd
Sulphur, % wt.	0.2-0.8	0.5 max.

DIFFICULTIES & SOLUTIONS

(1) PLUGGING OF INJECTOR TIP HOLES CAUSING SPRAY DISTORTION AND OIL DILUTION:

CHANGED TO NEEDLE VALVE INJECTORS.

(2) HIGH VAPOUR PRESSURES CAUSING VAPOUR LOCK:

REPLACED SUCTION FILTER WITH A STRAINER, RELOCATED FUEL HEATER TO DELIVERY SIDE OF PUMP, INCREASED SUCTION PIPE DIAMETER.

(3) FUEL FILTRATION - FILTER BLOCKING:

REPLACED PRIMARY (COTTON SOCK) AND SECONDARY (SINTERED BRONZE) FILTERS WITH 150 MESH SCREENS.

(4) INJECTOR CORROSION BY SALT, SALT WATER AND H_2S:

SPECIFIED COPPER STRIP CORROSION NO. 1 MAX.
SALT CONTENT 3LB NACL/1000 BBL

INVESTIGATED STAINLESS STEEL INJECTORS.

(5) "SOUPING" DURING PROLONGED IDLE, LUBRICATING OIL CONTAMINATION:

POSSIBLE REMEDIES INVESTIGATED.

(6) MODERATELY INCREASED WEAR OF CYLINDER LINERS:

ATTRIBUTED MAINLY TO "SOUPING".

CONCLUSIONS:

LABORATORY ENGINE TESTS AND MANY MILES OF ACTUAL RAILROAD OPERATION BY CN AND CP SHOW TECHNICAL SUCCESS BUT ENGINES WERE MUCH DIRTIER (MECHANICS COMPLAINTS) AND SOME INCREASE IN WEAR AND MAINTENANCE COSTS.

DID SHOW THAT IN A REAL EMERGENCY (I.E. EVEN WITHOUT REFINERY PRODUCTION) RAILWAYS COULD MAINTAIN OPERATIONS.

SELECTED PROPERTIES OF FUELS

	Synthetic Crude	Distillate Fuel Spec.
Specific Gravity 60°F	0.83-0.86	0.880 max.
Viscosity, cSt at 100°F	2.1-2.4	33 SUS min.
Flash point, °F	28	125 min.
Reid vapour pressure, psi	1.5-4	<1
Distillation, °F		
10% recovery	225-275	460 max.
50% "	500-550	535 max.
90% "	650-750	675 max.
Residue %	-2	-
Ash, % wt	0.002	Nil
Corrosion, Cu strip	No. 1	1A max.
Cetane number	35-37	45 min.
Pour point, °F	-15 to -35	As reg'd
Sulphur, % wt.	0.09-0.24	0.5 max.

LABORATORY ENGINE (EMD 567C) TESTS - SYNTHETIC CRUDE (1968)

EXHAUST TEMPERATURES
PEAK COMBUSTION PRESSURES
SPECIFIC FUEL CONSUMPTION
THERMAL EFFICIENCY
RING AND CYLINDER WEAR

} NO SIGNIFICANT CHANGE.

SLIGHT INCREASE IN EXHAUST EMISSIONS.
IGNITION DELAY: NO CHANGE AT IDLE.
: 1° CHANGE AT FULL LOAD.
SOUPING: BETTER THAN CONVENTIONAL DIESEL.

ROAD TESTS ON SYNTHETIC CRUDES

CANADIAN NATIONAL (1971)

4 EMD SD-40 3000 HP LOCOMOTIVES, 2 ON SYNTHETIC CRUDE, 2 ON CONVENTIONAL DIESEL.

MONITORED AT 15,000 MILE INTERVALS:

- LUBRICATING OIL (VISCOSITY, DIRT LOAD, WEAR)
- PISTON RING WEAR
- POWER ASSEMBLY WEAR
- INJECTOR PERFORMANCE
- GENERAL MAINTENANCE
- SYNTHETIC CRUDE PROPERTIES

AFTER 8 MONTHS (104,000 MILES) - NO SIGNIFICANT DIFFERENCES - FLEET EXPANDED TO YARD SWITCHERS.

SOME DIFFICULTIES WITH WAXING AT VERY LOW AMBIENT TEMPERATURES. LOW POUR SYNTHETIC CRUDE THEN SUPPLIED.

AFTER 12 MONTHS FLEET EXPANDED TO VIRTUALLY ALL REFUELLING AT EDMONTON.

CANADIAN PACIFIC (LATE 1970)

4 MLW CENTURY 424 LOCOMOTIVES (251 SERIES ENGINES)

10 MONTH COMPARATIVE TEST:

- 2 LOCOS ON SYNTHETIC CRUDE
- 2 LOCOS ON DIESEL FUEL.

MONITORED:

- FUEL CONSUMPTION
- POWER OUTPUT
- LUBRICATING OIL
- POWER ASSEMBLY WEAR
- ENGINE DEPOSITS

NO SIGNIFICANT DIFFERENCES EXCEPT SLIGHTLY HIGHER DIRT LOAD IN LUBRICATING OIL.

THIS FUEL FOUND A BETTER MARKET AND THUS BECOME UNAVAILABLE FOR RAILWAY USE.

SELECTED PROPERTIES OF FUELS

	Gas Oil Sidestream	Distillate Fuel Spec.
Specific Gravity 60°F	0.85-0.87	0.880 max.
Viscosity, cSt at 100°F	1.9-2.5	33 SUS min.
Flash point, °F	120-166	125 min.
Reid vapour pressure, psi	0.3	<1
Distillation, °F		
10% recovery	400-430	460 max.
50% "	450-480	535 max.
90% "	500-550	650 max.
Residue %	1-2	-
Ash, % wt	< 0.001	Nil
Corrosion, Cu strip	No. 1	1A max.
Cetane number	29-31	45 min.
Pour point, °F	-70 to -55	as reg'd
Sulphur, % wt.	0.00-0.15	0.5 max.

GAS OIL SIDESTREAM

SCREENING TEST:

EMD USED AN EMD 8-645E3 TURBOCHARGED ENGINE.

FINDINGS: WITH GAS OIL SIDESTREAM.

2-2 1/2% LOWER BRAKE SPECIFIC FUEL CONSUMPTION
NORMAL CYLINDER PRESSURES
1-1 1/2°GREATER IGNITION DELAY
SLIGHTLY LOWER SMOKE, LESS NO_X
MORE HYDROCARBONS AND CO PARTICULARLY AT IDLE.
RUNS TOO SHORT FOR WEAR DETERMINATIONS

BELIEVED LOW CETANE NUMBER WOULD GIVE CRANKCASE DILUTION AND HIGHER CARBON DEPOSITS AT IDLE.

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POSSIBILITIES FOR DIESEL LOCOMOTIVE FUELS

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POSSIBILITIES FOR LOCOMOTIVE DIESEL FUELS

1. INTRODUCTION

The supply and quality of diesel fuel oil used by Canadian railways has been under intensive study for the last five years. The railways, the fuel suppliers and various government agencies have carried out a number of investigations resulting in changes in the fuel being used. Further investigations now underway could be beneficial in reducing the overall Canadian petroleum demand as well as reducing fuel costs for railway transportation.

Early in 1979, the Petroleum Committee of the Canadian Government Standards Board (CGSB) set up a Sub-Committee on Middle Distillate Fuels with two working groups on burner fuels and diesel fuels. The Diesel Panel has provided an excellent forum for the interchange of information between the supply industry and the railways. The initial drive was to "loosen up" requirements in specifications which might unduly restrict supply. Changing conditions have avoided, or at least deferred, the spectre of fuel shortages[1]. But the work has been invaluable because all parties now have a greatly improved picture of the constraints of fuel supply and price and of engine limitations. The present need is for research into means of overcoming these constraints both to minimize petroleum demand and reduce transportation costs.

2. NATURE OF THE RAILWAY DIESEL ENGINE

Medium Speed Diesel Engines, running under full load at about 900 to 1100 rpm, have been the most usual choice for railway locomotives. These engines provide the optimum match between the limitations of railway loading gauge for weight, cross section and length and the requirements for horsepower, reliability and low maintenance costs. In contrast, engines for marine applications often are bulkier, heavier and run at low speeds while engines for automobiles, trucks and buses are more compact and run at higher speeds than the railway engines.

3. ENGINE DESIGN AND DIESEL FUEL

The speed of a diesel engine largely governs the type of fuel used. The faster running engine allows less time between fuel injection and exhaust valve opening, hence combustion must be completed more rapidly. The slow speed marine engines may be designed to burn a variety of fuels. Economics indicate use of cheaper, slow burning fuel. On the other hand, the high speed diesel engine used in automobiles and trucks is restricted to higher quality fuel. Because this higher quality fuel was so readily available and paradoxically, because it would be cheaper than a special medium speed engine fuel, produced in relatively small volume, consequently the railway engines have been designed with the high speed engine fuel in mind.

Historically then, railway engines have used fuel that met the #2D requirements of ASTM D 975[(2)]. Further Canadian refineries have supplied fuel exceeding the #2D specification especially in regards to sulphur and cloud point. Low sulphur means reduced engine wear. The cloud point is the temperature at which wax in the fuel is observed to come out of solution. This undissolved wax can block fuel filters. The implications of this are discussed in detail later in the paper.

Table 1 gives some of the requirements set out in CN Rail Specification 390-1C for "Railway Diesel Fuel"[(3)]. The grades of fuel are described by their cloud point in degrees Celsius. The summer fuel, grade #C-0, was supplied from April 1 to September 15 inclusive. The winter fuels, grades C-18, C-23, C-30, C-34 and C-40 are represented in Table 1 by the two extreme grades C-18 and C-40.

The next four sections of this paper will consider the effect of changes of four of the parameters in the specification.

4. FLASH POINT

After careful consideration and concurrence by the various Fire Commissioners, the Diesel Panel of CGSB made a change in 1979 lowering

the permissible Flash Point of Diesel Fuels from 125°F to 40°C[4]. It is unclear if this was successful in making much more fuel available. However it does allow future development of wider cut diesel fuels.

5. SULPHUR

To a major degree, sulphur as a limiting parameter has been eliminated through the use of crankcase oils with higher Total Base Number (TBN), that is oils with more alkalinity. Oils with a wide range of TBN are readily available and have been demonstrated to control corrosive wear of piston rings and cylinder liners.

6. CLOUD POINT

Once it was recognized that cloud point limitations were hindering use of lower cost fuels, then CN Rail proceeded to equip its locomotive fleet with larger fuel preheaters and a Hot Well circulating system. The fuel in the standard locomotive fuel system is heated in a cooling water/fuel exchanger, filtered and delivered to the engine. In the engine it enters the injectors and/or pumps for metering and combustion while at the same time lubricating the fuel pump plungers. The excess unburnt fuel cools the injectors and is returned to the main fuel tank. Figure 1 taken from CN Rail Report ME-51 "Locomotive Fuel Pre-heating Systems[5] illustrates the standard system for one model of locomotive with fuel temperatures as observed at idle. In the Hot Well system the excess hot fuel from the engine is no longer returned to the main fuel tank but to a small 9 to 10 gallon tank mounted on the end of the main tank which is typically 3000 gallons. The Hot Well then is filled with a mixture of the hot return fuel and enough 'make-up' cold fuel from the now unheated main tank. The system allows enough residence time for any undissolved wax in the cold fuel to redissolve before the mixture arrives at the filters. Figure 2 from Reference 5 shows test results for an engine running at full power. CN Rail expects to have all its locomotives equipped with Hot Wells at an early date. At that time low temperature fuel will not be required for the winter months. Wayside fuel handling

requires some consideration but no insurmountable problems are foreseen. The Fuels and Lubricants Laboratory and the Low Temperature Laboratory of the National Research Council Canada (NRC) are currently working in this area. The investigation[6] consists of studying engine filtration characteristics and wayside handling for a number of fuels and additives.

7. CETANE NUMBER

The combustion characteristics of various potential fuels are best determined, in our experience, by the engines themselves. It appears that for railway engines the significance of the cetane number of a fuel as determined with the special test engine and the ASTM D 613 procedure[7] is unclear. With heavier fuels, such as blends with residual Bunker C, it is necessary to modify the ASTM procedure.

Distillate fuels with cetain numbers in the low 30's have been used in CN engines without any apparent difficulty. The difficulties, which we will discuss, with residual fuel blends suggest that combustion is not adequately defined by cetane number. Cetane number is defined as a measure of ignition quality. Possibly there is need of a distinction between combustion and ignition qualities of fuel, which recognizes the operating speed and size of engine for which the fuel is intended.

8. USE OF FUEL FROM THE ATHABASKA TAR SANDS

Since 1972 millions of barrels of Gas Oil Side Stream Fuel from the Athabaska Tar Sands have been used by CN Rail in General Motors diesel engines. This fuel currently makes up about 18% of the fuel used by CN Rail. Maintenance and availability records for these engines have been indistinguishable from records for similar engines in our fleet using standard fuel. The Tar Sands fuel[8] has a Cetane Number of about 32. Table 2 gives some properties of this fuel.

9. USE OF #2 FURNACE OIL

Because of the successful experience of CN Rail with the low cetane Tar Sands fuel, it was decided to issue an economy fuel specification, with Furnace Oil in mind, see Table 3. In one case, this specification has led to the supply of a specially blended "RR #3" fuel, in other cases available furnace oil was offered and finally in some cases regular fuel was supplied at the lower furnace oil price. Each refinery acts and reacts differently to the overall supply of crude oil and demand for products because of limited short-term flexibility.

Table 4 illustrates some of the differences in the Furnace Oils that are available. While cloud point has been a limiting property for railway use, pour point is the critical property for home heating. The warmth in a basement provides the fuel with sufficient preheating for home heating use.

In Table 4 fuel from Refinery A has low cloud and pour points whereas fuel from Refinery B has a higher cloud point and a Pour Point Depressant additive must be used to obtain a suitably low pour point to permit easy delivery of this fuel for home heating. Refineries C and D present a similar case. Refineries E and F show two fuels both unsuitable for year-round railway use without preheating.

The uncertainty in the anticipated amounts of sulphur in fuel from Refineries B and F, Table 4, reflect uncertainty in availability of off-shore crude oils with relatively low sulphur. The high cetane number, 47.8, of fuel from Refinery E, Table 4, is considerably in excess of the company's minimum specification level.

Table 5 describes the fuel supplied for testing specifically meeting the requirements set out for economy fuel in Table 3. The viscosity is towards the lower end of the acceptable range. The sulphur is desirably low probably indicating use of Western Canadian crude oil and Tar Sand synthetic crude oil by the refinery. The cloud point is acceptable for railway use year-round without fuel preheating. The

low pour point of this fuel shows it has been treated with a Pour Point Depressant additive. This fuel has been used since the Fall of 1980 at one station both in the 50 locomotives assigned there and in visiting locomotives.

Table 6 shows the variation in cloud and pour points of four fuels supplied as winter fuel and used by CN Rail at one major location. Three of the fuels, including one offered as economy fuel, have cloud points that probably meet or exceed the 1% January Design Temperature for the given location whereas the fuel from Refinery G is borderline for the 2-1/2% January Design Temperature. It is expected that the fuel from Refinery G is, in fact, better than specified during most January's.

Table 7 shows the variation in cetane number between five fuels supplied to CN Rail. The difference between economy fuels and regular fuels is notable. Historically Furnace Oil has come from the same storage tank as the 45 cetane diesel fuel in some refineries.

Except where limited by cloud point to summer use: CN Rail has used all of the fuels described in Tables 4 to 7 for at least the last year with no known effect on engine performance. For example, wear metal levels in the crankcase oils have not changed. The fact is that the Middle Speed Diesel Engines used by the Railways are certainly able to burn lower quality fuels than the High Speed Diesel Engines used in automobiles and trucks. The steps taken by CN Rail to install Hot Wells will broaden the range of acceptable fuels. Two problems remain:

(1) To define the lowest limits of acceptable fuels, and

(2) To make these fuels more readily available.

Research work to define the lowest limits of fuel needs to be continued and expanded in the Canadian context: Not only is this an area of work for the railways, but government agencies such as NRC and the Naval

Engineering Test Establishment (NETE) and the Engine Builders need to be involved. The AAR supported project at the Southwest Research Institute[10] is noted. The work at NETE is to be reported by Bob Dunton, this afternoon. The NRC Railway Laboratory and the new Low Temperature Facility also have their place in this work.

The second point, namely, the need to make these fuels more readily available, involves the oil companies. Probably the best approach is to provide an arena for continuing frequent discussion between the fuel suppliers, the engine builders, the railways and the research workers and then allow market pressures to deliver or not to deliver the fuel. One such arena is the CGSB which should be encouraged to continue in this area. It is noted that the engine builder participation to date has not included the locomotive engine builders. Possibly the CGSB and/or NRC might consider also setting up panels, like the Diesel Panel, but with more specific terms of reference directed to guiding the indicated research investigations.

10. NATURE OF BLENDED FUELS

Blended fuels are fuels made of a mixture of distillate fuels, such as those described in the preceding section of the paper and residual fuels, typically described as Bunker C[11]. Such fuels are often described as containing a given percentage, say 10%, of Bunker C. However, 10% of one Bunker C fuel may make an acceptable blended fuel whereas 10% of another Bunker C fuel may give an entirely unacceptable blended fuel. Two new parameters in particular need to be considered, namely, compatibility, that is, stability of the mixture of fuels, and combustion characteristics.

The use of Furnace Oils as diesel fuels involved considerable discussion of cloud and pour points. Here we assume fuel preheating eliminates the need for considering cloud point but pour point will be important in regard to the handling of blended fuels. It is pointed out that cloud point is a nebulous term when dealing with black fuels such as

these blended fuels. The amounts of sulphur will likely be significantly higher and use of the more alkaline, higher TBN, crankcase oils is indicated.

Also, the presence of undesirable contaminants, such as vanadium and aluminum can occur. The aluminum comes from refinery catalysts in the form of abrasive fine aluminum oxide particles. Rejection of contaminated Bunker fuel is believed to be the only means of control. The use of additives may be able to provide acceptable control of reasonable levels of vanadium.

Research is needed to determine the nature of possible factors leading to fuel instability, that is, deposition of sludge in fuel tanks containing both blended fuels from different supplies and mixtures of blended and distillate fuels. Additives may be a possible answer but their selection and best means of use are believed to be largely unknown.

Research is needed to determine the limitations on fuel combustion. The problem of poor combustion at idle and low power is recognized. Work is needed to more clearly establish factors leading to the poor combustion, and the extent to which additives can help and engine modifications may be useful, feasible and practical. With this information it would be possible to determine where and when it is possible to use blended fuel 100% of the time vs. the complications of dual fuel operation. Dual fuel operation is, of course, use of a distillate fuel at idle and lower power and a blended fuel, probably with quite a high Bunker C content, at higher output power levels when combustion is quite complete. The single fuel system avoids the complications of dual fuel operation, including choice of operating ranges for each fuel and the extra equipment, but faces the difficulties of combustion at low power by using lower concentrations of heavy fuel in the blend.

In the 1950's and 1960's a number of American railroads[12] experimented with dual fuel systems. The Canadian railways working with NRC[13]

tested the possibilities of single fuel use of selected Canadian crude oils. It was concluded that maintenance costs were excessive for the then existing economic conditions.

In the 1980's the use of residual fuel blends is being reassessed both in the United States and Canada. The great increase in the costs of conventional diesel fuel has made the potential use of residual fuels, even with increased engine maintenance costs, extremely attractive to the engine operators. Answers are needed to the questions of how best to use these lower cost fuels in the diesel engines of the 1980's. There is also advantage to the oil companies and to the country in better use of each barrel of crude oil run by the refinery. Shifting some of the middle distillate, that is conventional diesel fuel, demand to the residual fuels eases the pressure on the relatively limited middle distillate supply. The loss in residual or heavy fuel oil supply for industrial heating can be made up by use of natural gas and coal.

11. NATURE OF "BUNKER C" OR #6 HEAVY FUEL OIL

The opening paragraph of a paper "Development of Marine Fuel Standards"[4] reads "There cannot be many other commodities, which have been marketed in such large quantities, for so long, without any quality controls that are recognizable by the customer." The reference is, of course, to Marine Fuels which are largely "Bunker C" and blends of it with middle distillate fuels.

The low quality end-product of most refineries is a semi-fluid black residue. The nature of this residue depends on the crude oils and processes used. Generally all the undesirable components, for example sulphur and vanadium, in the crude oil are concentrated in the residue. Some processes, for example catalytic cracking, may add undesirable comtaminants such as catalyst fines which are very abrasive. Finally, the highly viscous residues have to be cut back with any available low quality middle distillate liquids to produce heavy liquid fuel oil with a reasonably consistent viscosity called "Bunker C" or #6 Heavy Fuel Oil. Table 8 illustrates the limited

restrictions placed on the #6 fuel oil. It is noted that the two suppliers' specifications include 2 or 3 restrictions not given in the general specifications. However, it is quite apparent that except for viscosity, flash point and sulphur the heavy fuel oils are largely undefined. This is discussed in an excellent recent ASME paper by Sefer and Baker[15]. Attention is also drawn to the General Electric 'Class C' fuel specification[16] and a 'Proposed Fuel Property Guidelines' presented by the Association of American Railroads[17] for a blend of #6 and #2D fuels. These blends may be used in railroad locomotives with reasonable ease and minimum problems. However the blends so defined also restricts the amount of residual fuel component to a level giving only a small advantage in fuel cost savings.

12. SELECTION OF BLENDED FUELS

Beginning in 1981 CN Rail, with the assistance of one fuel supplier, has worked with blended fuels made with residual fuel from one refinery. The crude oils run by this refinery are neither the best nor the worst quality-wise. Consequently the blended fuels used are believed to be representative of the middle ground in the range of available heavy fuels. To optimize economic benefit the work started with blended fuel with a nominal 30% of Bunker. When and where difficulties ensued the blended fuel was diluted to lower nominal residual fuel concentrations with whatever middle distillate material was available either in the refinery or at the railway location. Blends have been diluted with heavy atmospheric gas oil, furnace oil and/or conventional locomotive diesel fuel. Table 9 gives the results of analyses of some of the blended fuels tested.

13. TEST EXPERIENCE WITH BLENDED FUELS - STATIONARY TESTS

All the stationary tests carried out by CN Rail to date have been made with an improvised set-up using one General Motors 3000 HP turbocharged diesel locomotive in Montreal. The fuel burnt in the test is measured and then dissipated in the banks of resistor grids provided in this particular unit for dynamic braking. These measurements and the required temperature measurements are made and recorded manually.

Some conclusions drawn from these short term tests are:

(1) Thirty nominal percent "Bunker C" blends can be burned at higher and full power with good combustion efficiency.

(2) Economic advantage is obtainable both from the lower cost of the fuel and the higher energy content of these denser fuels.

(3) Since railway operation may involve periods of prolonged idling, it was found that ten nominal percent "Bunker C" blends may be a present upper limit for blended fuels.

(4) Research is needed to investigate the several possible means of avoiding prolonged idling or overcoming the idling/combustion problem.

For the given model of test engine the mode of failure is deposit build-up on a screen in the exhaust system at the exhaust gas intake to the turbine of the turbocharger. If not stopped, the blockage on the screen leads to destruction of the turbocharger and/or an exhaust system fire. Figure 3 illustrates the nature of the deposit on the screen. This screen is about 18 inches in diameter of 1/4" steel plates and the holes being blocked by the deposit are 1/4" in diameter.

14. TEST EXPERIENCE WITH BLENDED FUELS - FIELD TRIALS

Currently the field trials underway at the CN Rail Hump Yard in Toronto involve 6 General Motors 3000 HP road locomotives similar to the one used in the stationary tests in Montreal and 4 General Motors 2000 HP diesel locomotives used in low-speed hump-switching operation. These 4 engines are not turbocharged, being normally aspirated, but otherwise are generally similar to the 6 road 16-645 model engines.

Some conclusions from these tests are:

(1) Ten nominal percent "Bunker C" blends can be used at any time of the year in Southern Ontario. The magnitude of the effects on engine wear and durability is still under study. The indications to date, see Table 10, show some increase in wear but this may well be acceptable given the economic advantages of the lower priced fuel.

(2) In times when the temperature is above 40°F, so that there is no danger of freezing up the cooling water, the engine can be shut down. By so avoiding prolonged idling, it will be possible to use a blended fuel with more than ten nominal percent residual fuel component.

15. ECONOMIC ADVANTAGES FROM LOWER COST FUELS

The bill for CN locomotive fuel is something over $300,000,000 per year. The use of furnace oil and all available Tar Sands fuel is estimated to reduce this fuel bill by some $3 to $4 million. The use of blended fuels where conceivably available in Eastern Canada could increase this saving by something like an additional $3 to $15 million depending on the "Bunker C" concentration. Such potential savings would outweigh even a sizeable increase in diesel engine maintenance costs.

16. SUMMING UP

Research is needed to enable the railways to use the lowest acceptable quality of fuel. Fuel oils now used for industrial heating are being replaced by natural gas. It should be possible to reduce the overall Canadian petroleum demand by working to shift the locomotive fuel consumption from the limited distillate diesel supply to the heavy gas oils and residual fuel oils and as needed by reviewing the refinery gasoline/distillate ratio and market situation. For the railways and the country, there is also the incentive of working to maintain low freight transportation costs.

17. ACKNOWLEDGEMENTS

The author must acknowledge that this paper is an overview of much work by many people for more years than those of us involved in it may like to admit. Some of the background of the work discussed here goes back at least twenty-five years. Canadian railways, fuel suppliers, engine builders and government agencies and laboratories have all contributed and cooperated with the aim of common advancement.

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TABLE 1 - TYPICAL CANADIAN RAILWAY DIESEL FUELS FROM CN SPECIFICATION 390-1C

Fuel Grade:	Summer Fuel C-0(1)	Winter Fuel C-18	Winter Fuel C-40	Test Method
• Viscosity at 40°C:				D 445
Centistokes, Min.	2.1	2.1	1.3	
Max.	4.5	4.5	2.5	
• Distillation:				D 86
90% Over at °C, Max.	345	345	325	
Recovery, % Vol., Min.	97.5	97.5	97.5	
• Flash Point, °C, Min.	50	50	40	D 93
• Sulphur, % Mass, Max.	0.5	0.5	0.5	D 129
• Cloud Point, °C, Max.	0	-18	-40	D 2500
• Pour Point, °C, Max.		TO BE REPORTED		D 97
• Cetane Number, Min.	40	40	40	D 613

NOTE: (1) April 1 to September 15 inclusive.

TABLE 2 - TYPICAL DIESEL FUEL FROM ATHABASKA TAR SANDS(1)

	Gas Oil Side Stream
• Viscosity at 40°C:	
Centistokes, Min.	2.0
Max.	2.5
• Distillation:	
90% Over at °C, Max.	345
Recovery, % Vol., Min.	97.5
• Flash Point, °C, Min.	45
• Sulphur, % Mass, Max.	0.2
• Cloud Point, °C, Max.	(2)
• Pour Point, °C, Max.	TO BE REPORTED
• Cetane Number, Min.	31

NOTES: (1) See references (3) and (4).

(2) Test response differs from that of standard fuel.

TABLE 3 - ECONOMY DIESEL FUEL SPECIFICATION

	Economy Fuel	Summer Fuel(1)
• Viscosity at 40°C:		
Centistokes, Min.	1.6	2.1
Max.	4.5	4.5
• Distillation:		
90% Over at °C, Max.	345	345
Recovery, % Vol., Min.	97.5	97.5
• Flash Point, °C, Min.	40	50
• Sulphur, % Mass, Max.	0.5	0.5
• Cloud Point, °C, Max.	(2)	0
• Pour Point, °C, Max.	(2)	TO BE REPORTED
• Cetane Number, Min.	30	40

NOTES: (1) From Table 1 - CN Specification 390-1C.

(2) 2.5% monthly design temperature - Reference 9.

TABLE 4 - TYPICAL ECONOMY DIESEL FUELS - 1
FROM REFINERIES A, B, C, D, E, AND F
SUPPLIER SPECIFICATIONS

	Refinery A	Refinery B	Refinery C	Refinery D	Refinery E	Refinery F
Serving Geographical Area:	X	X	Y	Y	Z	Z
• Viscosity at 40°C:						
Centistokes, Min.	1.8	1.5	1.8	1.6	1.8	1.9
Max.	3.3	3.2	3.3	3.2	3.3	3.2
• Distillation:						
90% Over at °C, Max.	300	357	300	357	300	357
Recovery, % Vol., Min.	97.5	98	97.5	98	97.5	98
• Flash Point, °C, Min.	46	40	46	40	46	40
• Sulphur, % Mass, Max.	0.5	0.5(2)	0.5	0.5	0.5	0.5(6)
• Cloud Point, °C, Max.	-23(1)	-9(3)	-16(4)	-12(3)	-9(3)	-12(3)
• Pour Point, °C, Max.	-33(1)	-42(3)	-21(4)	-39(3)	-30(3)	-39(3)
• Cetane Number, Min.	35	31	35	40	35(5)	31

NOTES:
(1) Fuel exceeds 2.5% MDT requirements can be used year-round.
(2) May require waiver to 0.7%.
(3) Fuel unsuitable without fuel preheaters between October 1 and March 31; fuel is pour depressed.
(4) Fuel borderline without fuel preheaters between October 1 and March 31; fuel is not pour depressed.
(5) Cetane number determined as 47.8 exceeding suppliers' minimum.
(6) May require waiver to 0.6%.

TABLE 5 - TYPICAL ECONOMY DIESEL FUELS - II

	Special Blend Economy Fuel
• Viscosity at 40°C: Centistokes	1.77
• Distillation:	
90% Over at °C	318
Recovery, % Vol.	98
• Flash Point, °C	48
• Sulphur, % Mass	0.28
• Cloud Point, °C	-24
• Pour Point, °C	Below -51 (1)
• Cetane Number	32.7 (2)

NOTES: (1) Fuel is pour depressed.

(2) Test carried out by National Research Council.

TABLE 6 - TYPICAL ECONOMY DIESEL FUELS - III
COMPARISON OF CLOUD/POUR POINTS - ONE GEOGRAPHICAL AREA

	Cloud Point[1]	Pour Point[1]
Refinery G	-6°C Max.[2]	-12°C Max.
Refinery H	-27°C Max.	-30°C Max.
Refinery I	-23°C Max.	-33°C Max.[3]
Refinery J	-21°C Max.	-25°C Max.

NOTES: (1) Supplier specification.

(2) Fuel borderline without fuel preheaters between October 1 and March 31.

(3) Pour depressed fuel.

TABLE 7 - TYPICAL ECONOMY DIESEL FUELS - IV
COMPARISON OF CETANE NUMBER RATINGS[1]

	Cetane Number ASTM D 613	
Refinery K	32.7	Economy Fuel
Refinery L	32.7	Economy Fuel
Refinery M	44.7	Competitive Offering
Refinery N	48.7	Competitive Offering
Refinery O	47.8	Competitive Offering

NOTE: (1) Tests carried out by National Research Council.

TABLE 8 - SPECIFICATIONS FOR "BUNKER C" OR #6 HEAVY FUEL OIL

	ASTM D 396-80[1] CAN2-3.2M81[1]	Company A[3]	Company B	Test Method
Density at 15°C in kg/m^3	NS[2]	NS	995.9	D 1298
Viscosity at 50°C:				D 445
Centistokes, Min.	92	328	476	
Max.	638	424	635	
Flash Point, °C, Min.	60	65.6	66	D 93
Sulphur, % Mass, Max.	NS	3	3	D 552
Ash, % Mass, Max.	NS	0.1	NS	D 482
Water and Sediment, % Vol., Max.	2.0	1.0	1.0	D 95/D 473

NOTES: (1) From reference 11.

(2) Not specified.

(3) Offered as "Bunker C" but limit on maximum viscosity permits description also as "Marine Bunker".

TABLE 9 - ANALYSES OF SOME BLENDED FUELS

Nominal % "Bunker C"	30	30	30	20	10	30
Sample Date	Oct. 28/81	Jan. 20/82	Mar. 17/82	May 17/82	Oct. 22/82	Nov. 12/82
Density, kg/m^3	904	913	893	878	882	915
Viscosity in cSt.						
at 40°C	17.59	17.19	14.85	6.9	4.24	15.32
at 100°C	3.95	3.92	3.55	2.15	1.57	3.61
Distillation,						
50% Over at °C	317	313	316			
Recovery, % Vol.	90.5	83.0	91.5			
Water, % Mass		-	Nil	Nil	Nil	<.005
Sediment, % Vol.						
Ash, % Mass	0.011	0.015	0.015			0.011
Sulphur, % Mass	0.73	0.68	0.65	0.54	0.46	0.81
BTU/lb.	19,258	19,212	18,841			18,763
BTU/gal.	174,092	170,670	172,020			171,682
Conradson Carbon % Mass	4.8	5.3	4.6	3.3	2.0	5.3[5]
Vanadium, ppm Mass	12.					24.
Sodium, ppm Mass	20.	20.	20.		7.	20.
Nickel, ppm Mass	25.	20.	20.		10.	20.
Aluminum, ppm Mass	1.	3.	3.		1.5	3.

TABLE 10 - TRENDS IN USED OIL ANALYSES FOR ENGINES ON BLENDED FUELS

Oil now in use is Gulf Ralube 950HT - 7 TBN

- Oil changes due to loss of alkalinity (low pH, low TBN):

  5 Road Units - 2 to 3 months (9640 4-1/2 months)

  1 Road Units 9655 with E3B assemblies
  - 6+ months

  3 Hump Units - about 3 to 4 months

- Typically oil at change a/c low TBN shows

Silver	2X normal(1)	(no silver 9655)
Copper	normal	
Lead	normal	
Iron	2X normal(1)	especially for liner metal
Chromium	2X normal(1)	
Sodium	normal	
Aluminum	normal	
Silicon	normal	
Zinc	normal	

  Viscosity increase of 5% above normal(2)

  Absorbance 2X normal(3)

(1) Presumed metal from all assemblies rather than debris from mechanical distress from one assembly.

(2) Measurable, but not significant.

(3) Amounts of dirt in oil in hump units is fairly high.

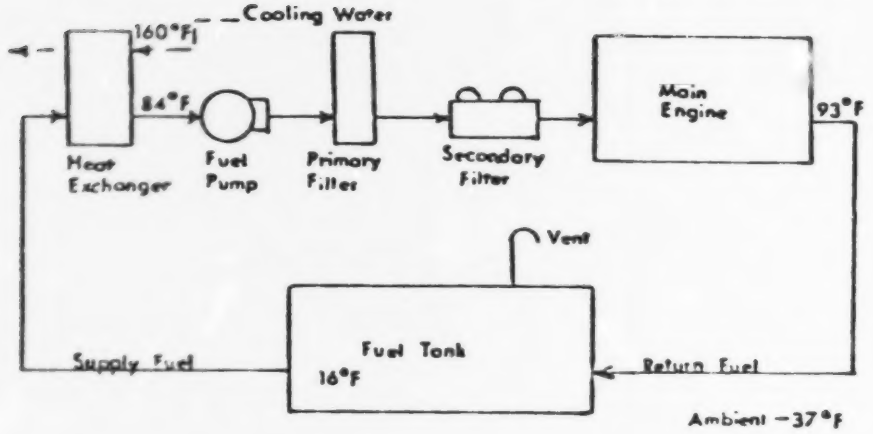


FIGURE 1

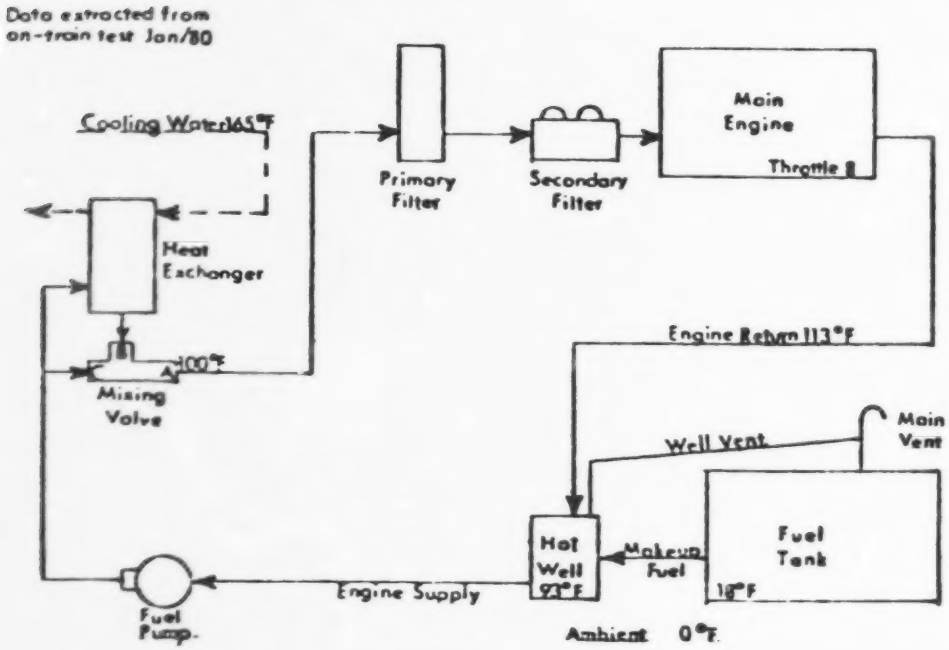
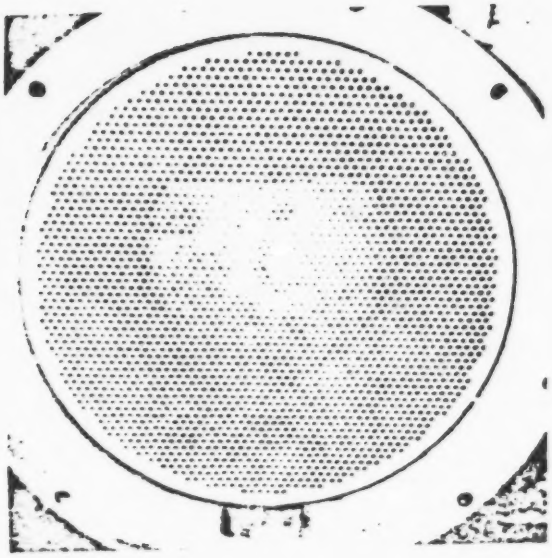
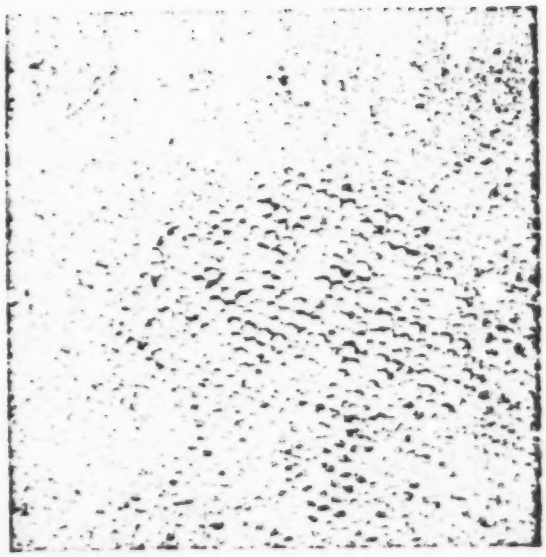
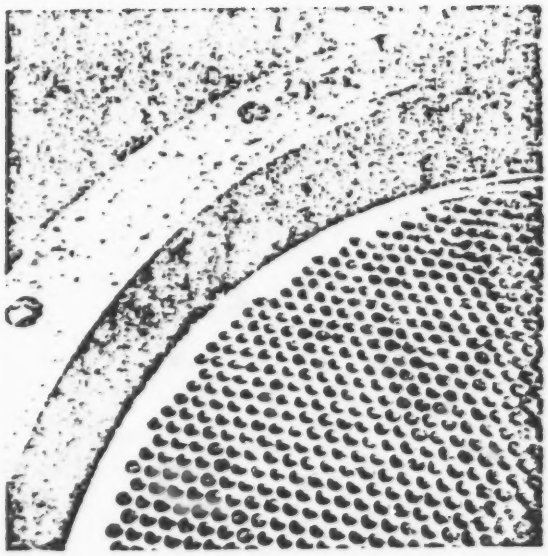


FIGURE 2







April 26-29, 1982 (5257)

Turbo Protective Screen
After 72 Hour Idle Test
Burning 20% Bunker

FIGURE 3

EMD TURBOCHARGER PROTECTIVE SCREEN

ALTERNATIVE FUELS TESTING BY BOMBARDIER

Robert M. Dunton
Director of Engine R & D
Bombardier Inc.,
Rail & Diesel Power Products Division

ALTERNATE FUELS TESTING BY BOMBARDIER

RAILWAY ENERGY SEMINAR
TRANSPORT CANADA
MARCH 15, 1983

R.M. Dunton

INTRODUCTION

This programme has been underway in Bombardier for over a year. Funding has been provided by several Canadian Government Departments, channeled through the Department of National Defence.

We took advantage of the existence of a test cell at the Naval Engineering Test Establishment in LaSalle. In fact we had been using this cell for about a year before starting this programme. We have been able to start this work earlier, since construction of new cells takes considerable time. In fact, we commissioned on first new cell in October 1982.

The engine we selected for this programme is a 12 cylinder 251F, with a maximum horsepower of 3000 at 1100 rpm. This particular engine will give us the most critical evaluation of fuels, this ensuring that fuels which pass testing in this engine will be acceptable in engines in service at lower horsepower ratings.

1982/83 PROGRAMME

The principal objective of our work during the past year, after completing the instrumentation and the basic de-bugging and calibration of the instrumentation, was to establish the performance characteristics of off-specification diesel fuels.

There has been no attempt made to evaluate long-term effects of operation with these fuels, nor has there been any attempt to adjust the engine in any way to improve performance. We were interested only in determining the behaviour of these fuels in a 251 engine, in order to determine future areas for testing leading to improvement of performance.

SELECTION OF TEST FUELS

The reference is a standard commercial ASTM NO 2D fuel. We obtained a total of 35000 gallons of this fuel, in order that we can make check runs of baseline performance throughout the programme. The engine was operated with this reference fuel before and after each alternate fuel test.

Fuel B was chosen as an example of a fuel with a high end point, since a simple approach to broadening the diesel fuel extracted from available crude is to expand the distillation range. This fuel is otherwise conventional.

Fuel C is a fuel specially blended to simulate the "1990" projected fuel. That is, the best prediction of the diesel fuel available in 1990. Considering recent events, it perhaps should be re-named 1995 to 2000. Significant are the high percentage of hydro-cracked components, high aromatic content, and low cetane (estimated 32).

Fuel D is the Fort McMurray Tar Sands blend which has been used for some time by Canadian Railways in the west.

Fuel E is commonly called N° 3 RR, which also is in current use. This fuel is essentially a modified heating oil.

Fuel F is a blend of 25% N° 6 with 75% N° 2 which has been provided by Imperial to a number of customers as a heating oil. This is our first cut at a blended fuel.

PRELIMINARY RESULTS

We are in the first place trying to determine if any of these fuels are likely to have performance characteristics which might lead to problems with reliability, durability, and maintenance cost.

Firstly, fuel injection equipment, and the fuel pump drive system. The measured injection pressure indicates that the loading on this system is not increase significantly. It is not surprising that the Blended fuel (F) shows the greatestincrease in fuel injection pressure, since the viscosity is significantly higher, even when pre-heated. We have limited our pre-heating to 65°C (155°F), which can be achieved using locomotive cooling water.

The next characteristic is combustion delay, which is related to cetane Number. This gives us the primary indication of combustion conditions which may lead to high peak pressures, poor efficiency, and possibly high exhaust temperatures. It also provides an indication of the potential for adjustments to fuel injection timing. The results are not surprising, since they tend to confirm the laboratory measuremoents of of the fuels. The fuels closer to normal with low cetane have as expected, the greatest increase in delay.

Maximum rate of pressure rise is the early indication of knock or detonation, and is, of course, an indicator of potential mechanical damage in reciprocating components. This is the maximum rate, i.e the highest rate measured during a measurement interval of the combustion pressure trace. Again the results are surprising. While we do see some increase over baseline, we have not detected any sensible knock, and do not yet see any cause for concern. It is encouraging to see the good behaviour of the blended fuel (F).

Maximum cylinder pressure is another important indicator of mechanical loading. Every fuel shows some increase, but even the 2000 psi is not cause for concern, since we have had many engines operating for up to 10 years with maximum cylinder pressures at this value.

Smoke is always important, not only because it is an undesirable pollutant, but also as an indicator of less than desirable combustion conditions. The only significant result obtained is again predictable, it reflects the poor low-load combustion of the blended fuel.

Finally, we come to the craunch the fuel consumption. We have plotted here the relative brake specific fuel consumption in pounds per broke horsepower hour. No correction has been made because we are still awaiting credible data on the heating value of each fuel. These results are rather discouraging, because they tend to show that some of the marginal cost savings from using these fuels may be offset by poorer performance. We must recognize that to date no attempt has been made to optimize performance with any of these fuels. We will also analyse this data further before arriving at any final conclusions.

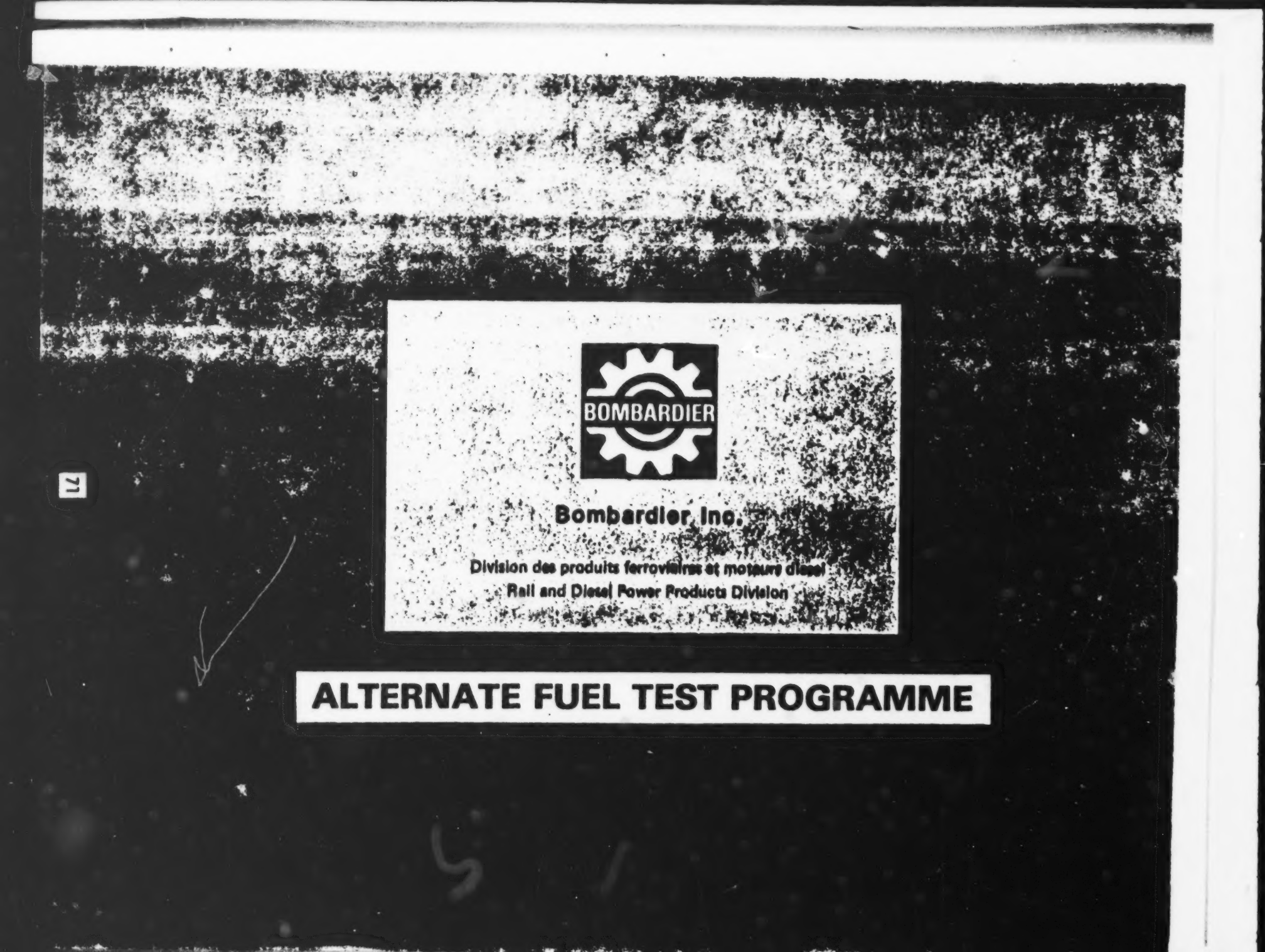
FUTURE WORK

Near term, we will begin engine optimization to find appropriate ways to adjust engines for improved performance, and will conduct a 72-hour idling test with blended fuel F.

After that, we will probe more deeply into improving the performance on selected fuels, and will produce a preliminary guideline for fuels which can be used in the 251 engine.

We have also recently established contacts with two users of 251 engines who have been using heavier fuels for some time. We have just started our detailed investigation of these. We hope within a few months to have a significant amount of data about heavier fuels in 251 engine.

This is only the beginning. Liquid petroleum fuels of the future will change significantly the basic combustion behaviour of medium-speed engines, and this must be explored and understood in order that all engine users can obtain the optimum in fuel economy.


BOMBARDIER
Bombardier Inc.
Division des produits ferroviaires et moteurs diesel
Rail and Diesel Power Products Division
ALTERNATE FUEL TEST PROGRAMME

TEST PROGRAMME FOR 1982/83

72

Performance limits of off-specification diesel fuels

RATIONALE FOR TEST FUELS SELECTION

FUEL "A"

REFERENCE FUEL

- Conventional ASTM No. 2D

FUEL "B"

ULTRAMAR FUEL

- A high end point No. 2D
- Chosen to examine the effect of extended distillation range of engine combustion

FUEL "C"

NRC 1990 FUEL

- A mix of tar sand and western crudes and 22% of hydrogen treated cracked stock
- Chosen for its high aromatic and low cetane level

RATIONALE FOR TEST FUELS SELECTION (Cont'd)

FUEL "D" — TAR SAND BLEND

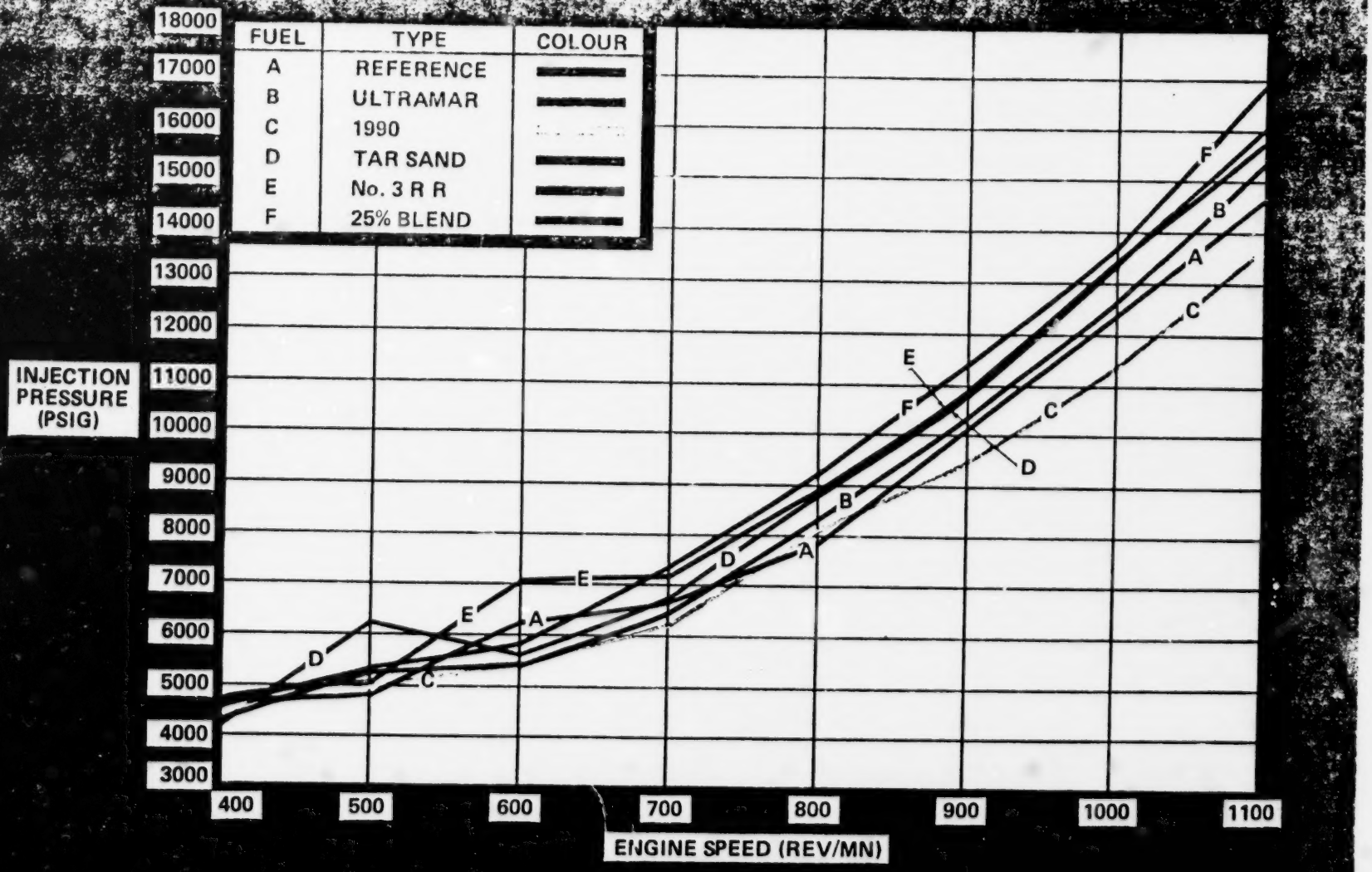
- A 50/50 mix of gas oil side stream and heavy unified gas oil from fort McMurray
- Chosen for its high aromatic, broad distillation range and low cetane level

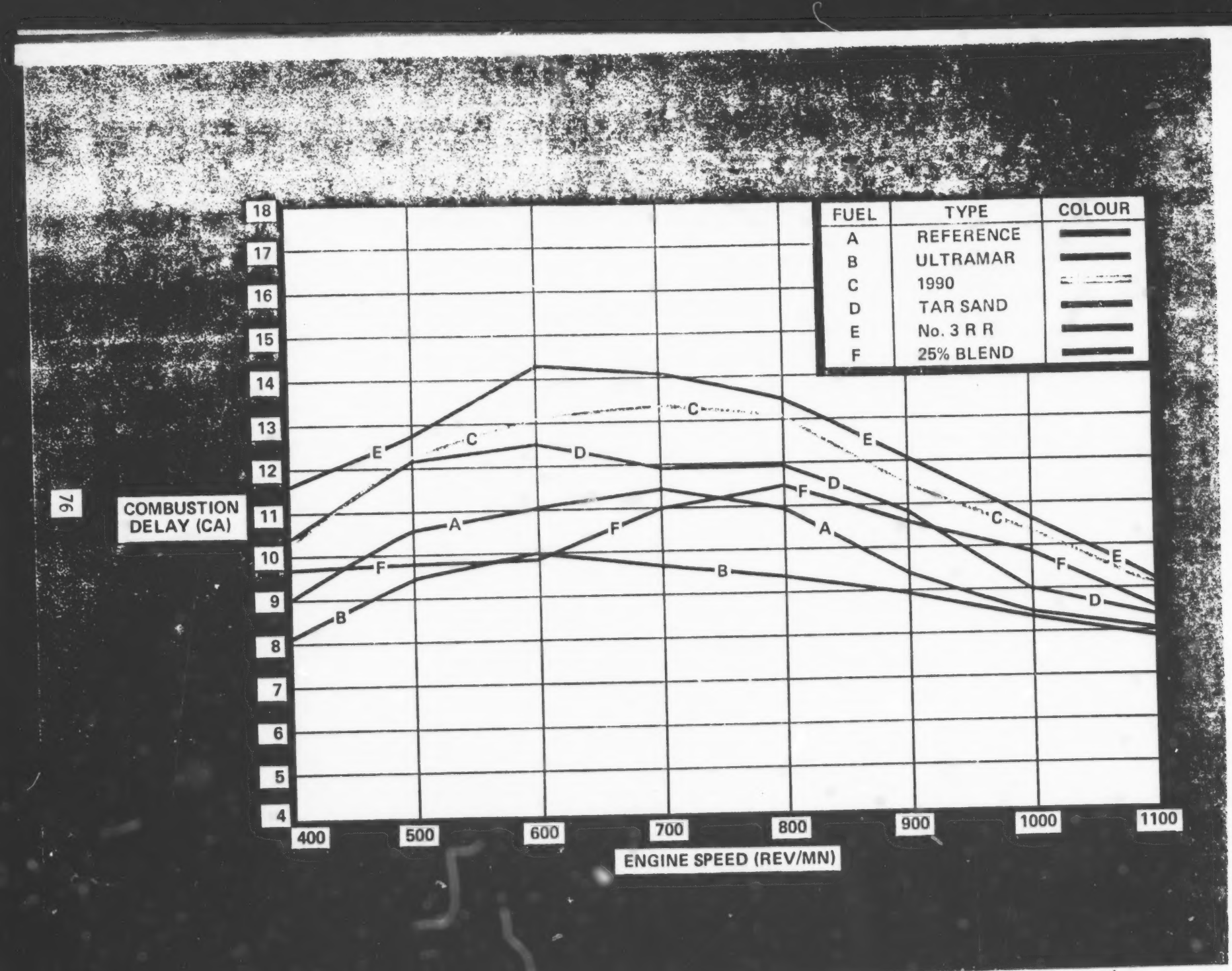
FUEL "E" — NO. 3RR FUEL

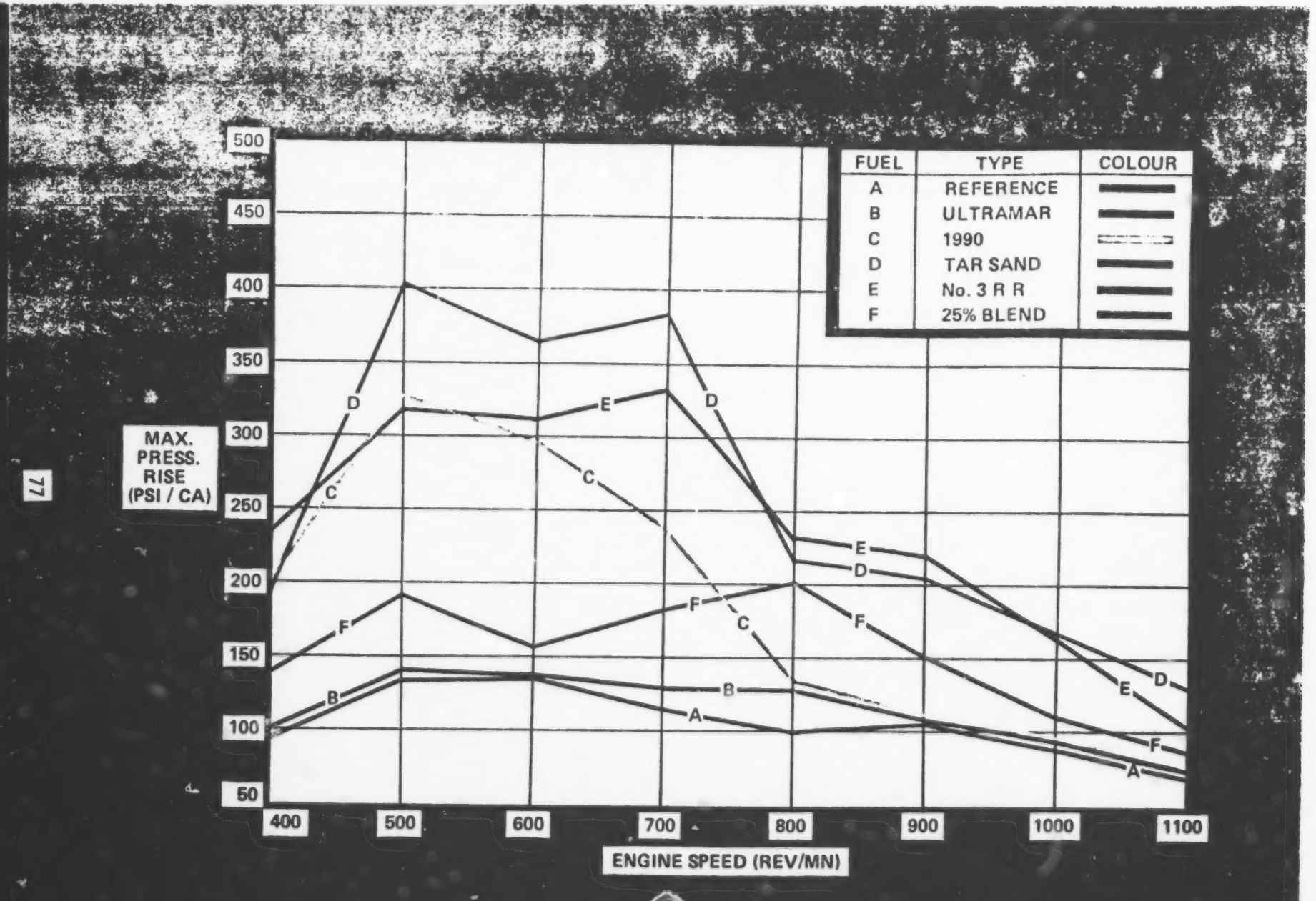
- A ASTM no. 2 heating oil containing stabilized cracked stock
- Chosen for its availability and economy. This fuel is currently used by the Canadian railroads

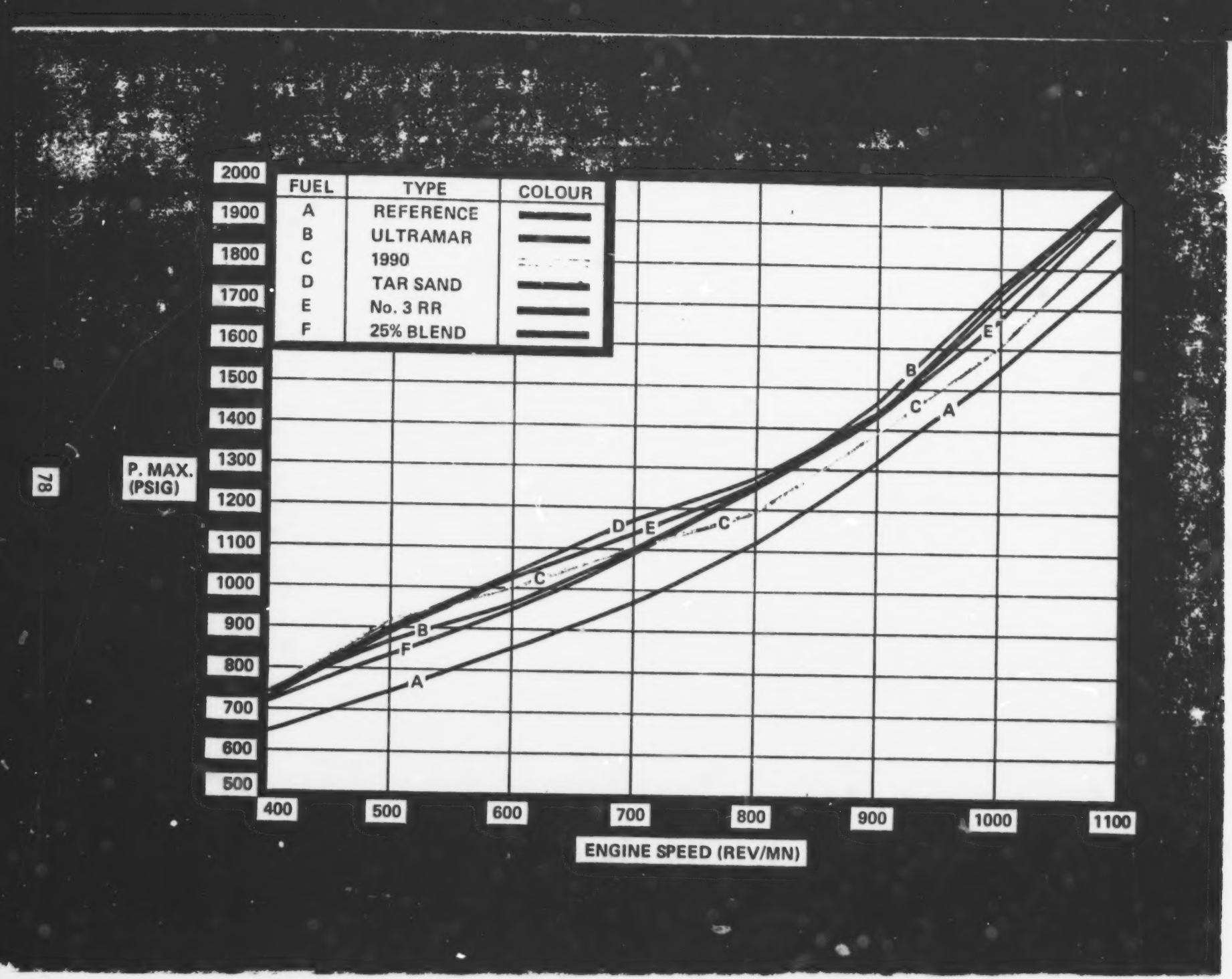
FUEL "F" — HEAVY FUEL

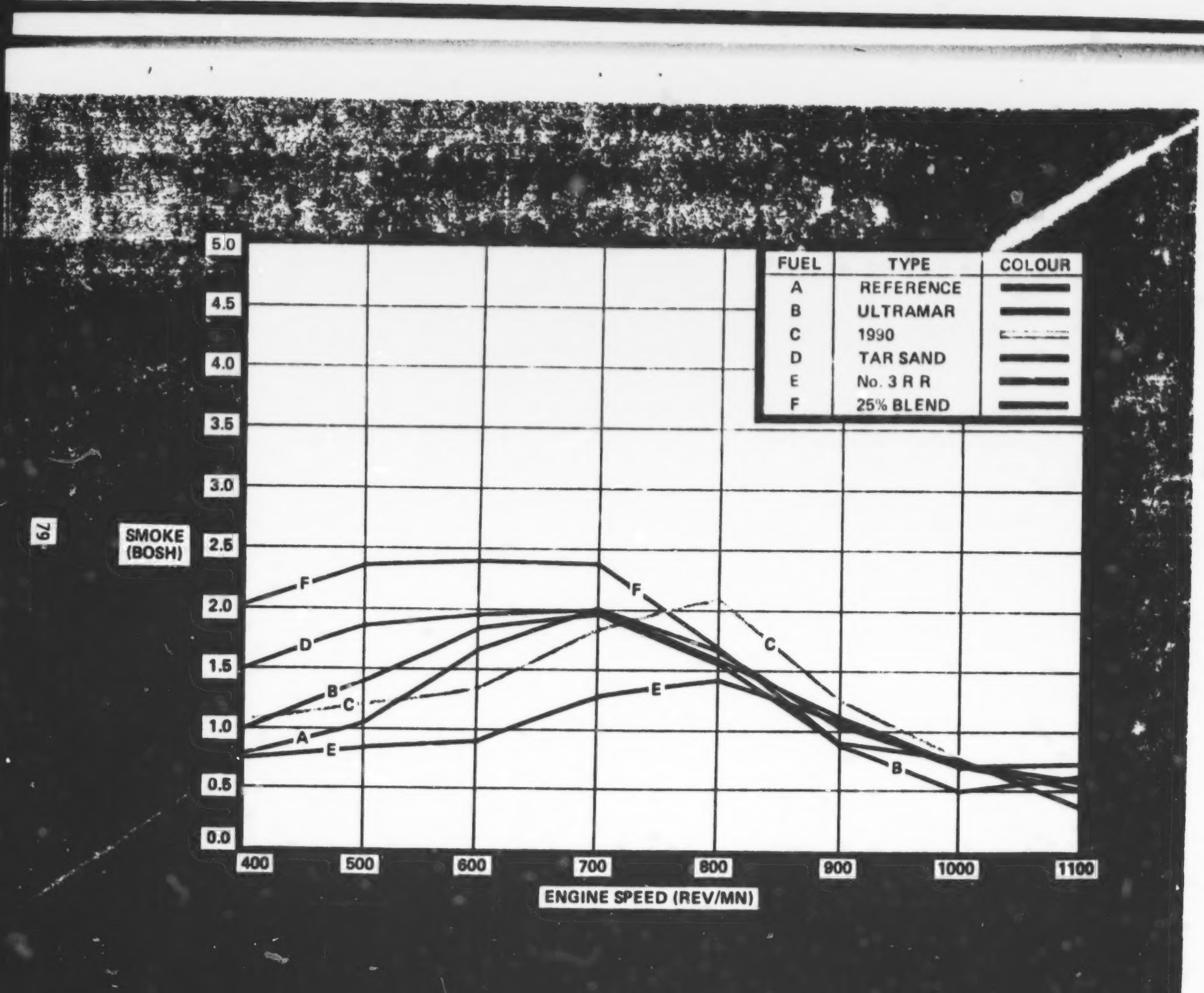
- A blend of 25% ASTM no. 6 and 75% ASTM no. 2D fuels
- Chosen for economic advantage

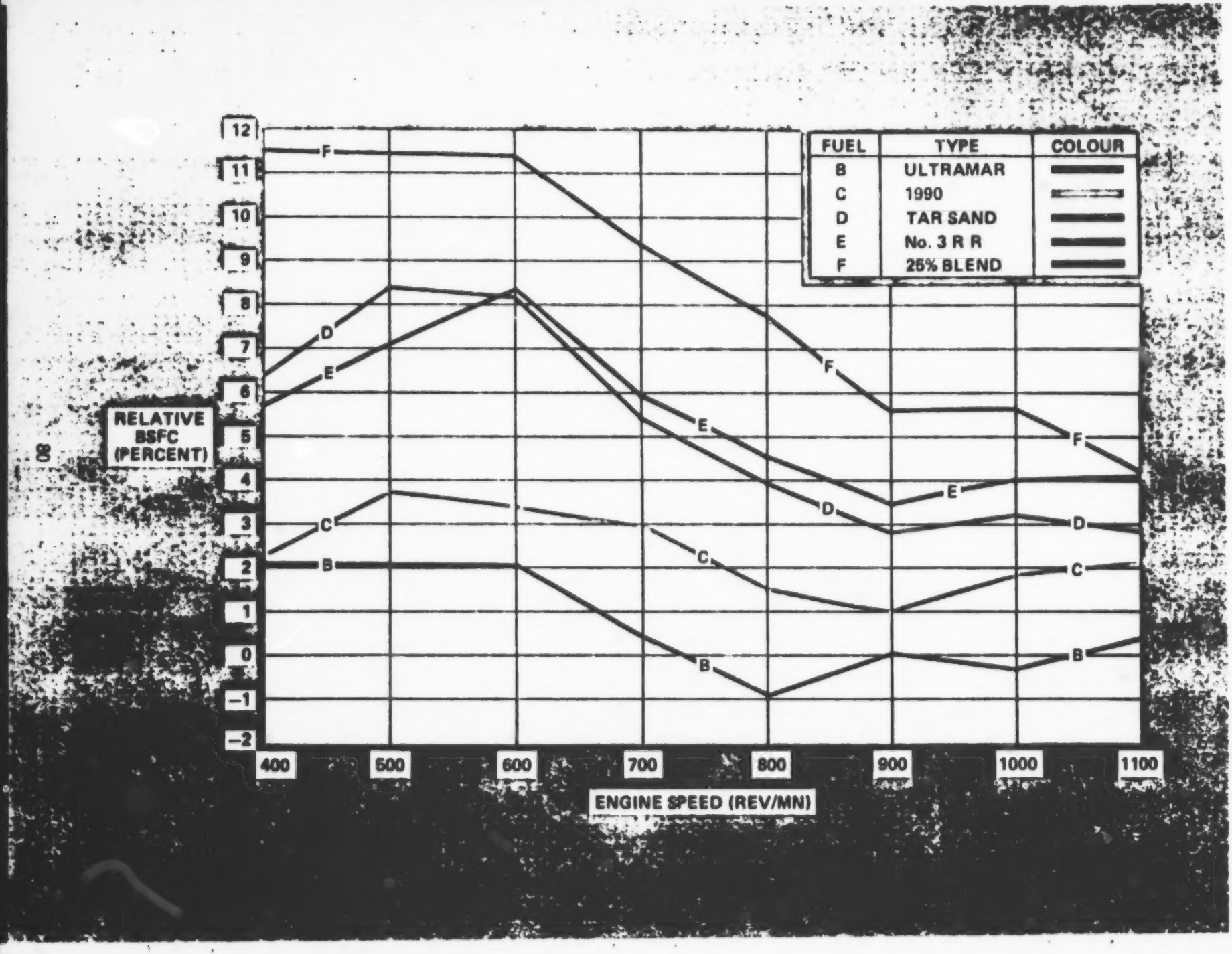

FUEL
TYPE
COLOUR
A
REFERENCE
B
ULTRAMAR
C
1990
D
TAR SAND
E
No. 3 R R
F
25% BLEND
INJECTION PRESSURE (PSIG)
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
400
500
600
700
800
900
1000
1100
ENGINE SPEED (REV/MN)

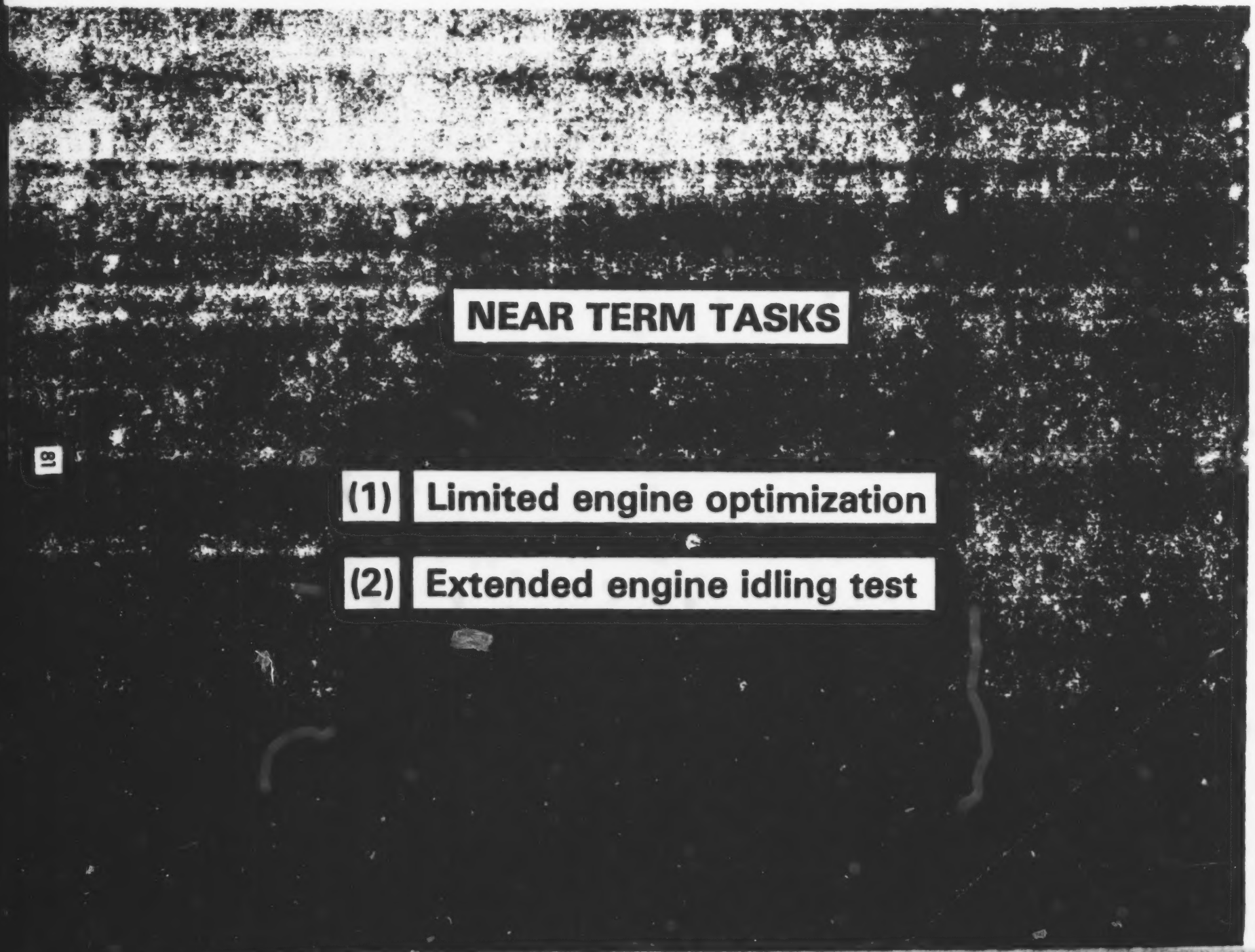

FUEL
TYPE
COLOUR
A
REFERENCE
B
ULTRAMAR
C
1990
D
TAR SAND
E
No. 3 R R
F
25% BLEND
COMBUSTION DELAY (CA)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
400
500
600
700
800
900
1000
1100
ENGINE SPEED (REV/MN)


FUEL | TYPE | COLOUR
A | REFERENCE
B | ULTRAMAR
C | 1990
D | TAR SAND
E | No. 3 R R
F | 25% BLEND
MAX. PRESS. RISE (PSI / CA)
500
450
400
350
300
250
200
150
100
50
400
500
600
700
800
900
1000
1100
ENGINE SPEED (REV/MN)


FUEL
TYPE
COLOUR
A
REFERENCE
B
ULTRAMAR
C
1990
D
TAR SAND
E
No. 3 RR
F
25% BLEND
P. MAX. (PSIG)
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
500
600
700
800
900
1000
1100
ENGINE SPEED (REV/MN)


FUEL | TYPE | COLOUR
A REFERENCE
B ULTRAMAR
C 1990
D TAR SAND
E No. 3 R R
F 25% BLEND
SMOKE (BOSH)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
400
500
600
700
800
900
1000
1100
ENGINE SPEED (REV/MN)
F
D
B
C
A
E
F
C
E
B


FUEL
TYPE
COLOUR
B
ULTRAMAR
C
1990
D
TAR SAND
E
No. 3 R R
F
25% BLEND
RELATIVE BSFC (PERCENT)
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
400
500
600
700
800
900
1000
1100
ENGINE SPEED (REV/MN)


NEAR TERM TASKS
(1) Limited engine optimization
(2) Extended engine idling test

MEDIUM TERM OBJECTIVE

(1) Detailed investigations for a maximum of two fuels selected from 1982/83 testing.

(2) Issue fuel specification(s) guidelines for engine users and oil refineries.

FUEL CONSUMPTION OF GENERAL MOTORS DIESEL LOCOMOTIVES

King C. Langtry
Sales Manager
Railway & Power Products
General Motors of Canada, Diesel Div.

SLIDE	
1. DD LOGO	GOOD MORNING. I AM PLEASED AND HONORED TO PARTICIPATE IN THIS TRANSPORTATION ENERGY SEMINAR.
2. ENERGY COSTS CDN RWYS	THE CANADIAN RAILWAYS CONSUME SOME 500 MILLION GALLONS OF FUEL ANNUALLY.
3. CN SD40-2	GENERAL MOTORS 3000 HP LOCOMOTIVES CONSUME A LARGE PORTION OF THIS FUEL.
4. CP SD40-2	THERE ARE 1,241 SUCH UNITS IN OPERATION ON THE CANADIAN RAILWAYS.
5. QNS&L SD40-2	MY PRESENTATION WILL DESCRIBE THE DESIGN CHANGES SINCE 1978.
6. BCR SD40-2	TO REDUCE THE FUEL CONSUMED BY THIS CLASS OF LOCOMOTIVE.

7. ENGINE THERMAL EFFICIENCY & SUPPORT SYSTEMS

WE WILL BE LOOKING AT THERMAL EFFICIENCY IMPROVEMENTS IN THE ENGINE AS WELL AS REDUCTIONS IN FUEL CONSUMED TO DRIVE THE LOCOMOTIVE SUPPORT SYSTEMS.

8. SUPPORT SYSTEMS

WHICH INCLUDE THE RADIATORS, COOLING FANS, THE TRACTION MOTOR AND MAIN GENERATOR BLOWERS, THE AIR COMPRESSOR AND AUXILLIARY GENERATOR.

9. AUXILLIARY HP

THESE AUXILLIARIES CAN ABSORB UP TO 8½% OF THE HP DEVELOPED BY THE ENGINE INDIRECTLY CONSUMING A CORRESPONDING AMOUNT OF FUEL.

10.	MEDIUM DUTY CYCLE	THE FUEL CONSUMPTION REDUCTIONS THAT I WILL BE DESCRIBING WILL BE MEASURED ON THE BASIS OF THEIR IMPACT ON THE FUEL CONSUMED DURING A MEDIUM DUTY LOCOMOTIVE CYCLE I.E. A LOCOMOTIVE OPERATING IN 8TH THROTTLE POSITION, 17% OF THE TIME, IDLING 46% OF THE TIME, DYNAMIC BRAKING 9% OF THE TIME AND OPERATING IN EACH INTERMEDIATE THROTTLE POSITION 4% OF THE TIME.
11.	SD40-2 ANNUAL FUEL CONSUMPTION	A 1978 MODEL SD40-2 LOCOMOTIVE WHICH IS AVAILABLE FOR SERVICE 90% OF THE TIME AND OPERATING ON THIS MEDIUM DUTY CYCLE WOULD BE EXPECTED TO CONSUME 333,333 GALLONS OF FUEL ANNUALLY.
12.	1979 IMPROVEMENTS	WE WILL LOOK FIRST AT THE 1979 IMPROVEMENTS.

13.	E3B ENGINE	THE E3B ENGINE INCLUDES AN IMPROVED TURBO CHARGER WITH HIGHER FLOW EFFICIENCY AND A NEW DESIGN FUEL INJECTOR WITH INCREASED DIAMETER PLUNGER.
14.	EB TURBO CHARGER	THE TURBO CHARGER TURBINE BLADE AND NOZZLE AND THE COMPRESSOR DIFFUSER WERE REDESIGNED.
15.	TURBINE BLADE	THE TURBINE BLADES HAVE AN IMPROVED AIR FOIL SHAPE.
16.	TURBINE NOZZLE	THERE WERE MATCHING CHANGES TO THE NOZZLE FOR MORE GRADUAL GAS TURNING AND IMPROVED TURBINE EFFICIENCY.
17.	COMPRESSOR DIFFUSER	A VANE ISLAND DESIGN HAS BEEN USED FOR THE COMPRESSOR DIFFUSER.

18. COMPRESSOR DIFFUSER	REPLACING THE CURVED AIR FOIL DESIGN. THESE DESIGN CHANGES RESULT IN IMPROVED PRESSURE RECOVERY AND COMPRESSOR EFFICIENCY.
19. 1" INJECTOR	THE FUEL INJECTOR PLUNGER DIAMETER WAS INCREASED FROM .453" TO ½" FOR A HIGHER FUEL INJECTION RATE.
20. INJECTOR TIMING	USING THE SAME INJECTION START TIMING, INJECTION IS COMPLETED 5° EARLIER IN THE CYCLE, ALLOWING MORE TIME FOR MORE COMPLETE BURNING OF THE FUEL.
21. 1979 SUMMARY	THE RESULTS OF THESE 1979 CHANGES IS AN OVERALL IMPROVEMENT OF 1.8% IN FUEL EFFICIENCY OR A POTENTIAL ANNUAL SAVINGS OF 6,084 GALLONS OF FUEL FOR AN SD40-2 LOCOMOTIVE OPERATING ON THE MEDIUM DUTY CYCLE.

22.	1980 IMPROVEMENTS	THE FUEL SAVINGS IMPROVEMENT THAT WAS READY FOR RELEASE IN 1980
23.	2 SPEED D.B. (315 RPM)	HAD TO DO WITH THE ENGINE SPEED DURING DYNAMIC BRAKING. PREVIOUSLY THE ENGINE WAS RUN AT 4TH THROTTLE POSITION OR 560 RPM. THIS CHANGE PERMITS THE ENGINE SPEED TO DROP TO IDLE SPEED OR 315 RPM WHEN THE DYNAMIC BRAKE DEMAND IS BELOW 600 AMPS, WITH A 52% SAVING IN FUEL WHILE OPERATING IN THIS MODE.
24.	1980 SUMMARY	THIS RESULTED IN AN ADDITIONAL .3% SAVING ON THE MEDIUM DUTY CYCLE OR 1,014 GALLONS PER YEAR.
25.	1981 IMPROVEMENTS	THE 1981 IMPROVEMENTS INCLUDE CHANGES TO THE ENGINE IDLE SPEED AND THE EXHAUST SILENCER.

26. LOW/IDLE 255 RPM — THE IDLE SPEED WAS REDUCED FROM 315 TO 255 RPM, REDUCING FUEL CONSUMPTION BY 21% WHILE OPERATING IN THIS MODE.

27. 2 SPEED DB 255 RPM — AT THE SAME TIME THE LOW ENGINE SPEED FOR DYNAMIC BRAKING WAS REDUCED TO 255 RPM GAINING ANOTHER 3 PERCENTAGE POINTS WHILE IN THIS MODE.

28. ENGINE SILENCER — A STRAIGHT THROUGH EXHAUST SILENCER WAS DESIGNED WITH NO MORE BACK PRESSURE THAN THE ORIGINAL STRAIGHT MANIFOLD, BUT STILL MEETING SOUND EMMISSION STANDARDS.

29. 1981 SUMMARY — THESE CHANGES REDUCED THE FUEL CONSUMPTION ON THE MEDIUM CYCLE ANOTHER 1.1% FROM THE 1978 LEVEL.

30. 1982 IMPROVEMENTS — BY 1982 MANY DEVELOPMENTS WHICH HAD BEEN IN WORK FOR SEVERAL YEARS WERE READY FOR RELEASE ALONG WITH THEIR FUEL SAVINGS PAY OFFS.

31.	FIRE RING PISTON	THE TOP COMPRESSION RING IN THE ENGINE WAS MOVED UP ½" TO THE 3/4" LEVEL, EFFECTIVELY INCREASING THE LENGTH OF THE POWER STROKE.
32.	HARDENED UPPER BORE	AS WITH MANY OF THE OTHER FUEL SAVINGS MEASURES TAKEN, A CORRESPONDING ENGINE DURABILITY CHANGE WAS MADE. THE UPPER LINER BORE WAS LASER HARDENED TO REDUCE WEAR AND SCUFFING. THIS PROCESS HAD BEEN USED IN THE PORT AREA SINCE 1978.
33.	MODIFIED EB TURBO	THE EB TURBO CHARGER WAS REMATCHED TO THE PERFORMANCE CHARACTERISTICS OF THE NEW FIRE RING ARRANGEMENT.
34.	LOW IDLE 235 RPM	THE ENGINE IDLE SPEED WAS FURTHER REDUCED TO 235 RPM.
35.	2 SPEED DB 235 RPM	AND A CORRESPONDING CHANGE IN THE ENGINE RPM DURING LOWER DEMAND DYNAMIC BRAKING.

36. 3½ RAD CORES	THE ENGINE COOLING RADIATOR SURFACE AREA WAS INCREASED 16 2/3% AND THE NUMBER OF BLADES ON EACH COOLING FAN WAS REDUCED FROM 9 TO 6 REDUCING THE COOLING FAN POWER REQUIREMENTS.
37. UNLATCHED FANS	THE COOLING FAN CONTROL CIRCUITRY WAS MODIFIED PERMITTING FANS TO BE TURNED OFF INDIVIDUALLY AS WELL AS ON INDIVIDUALLY.
38. TM BLOWER DUCT	THE TRACTION MOTOR BLOWER DUCT WAS MODIFIED FOR LESS RESISTANCE TO AIR FLOW.
39. TM BLOWER	THE TRACTION MOTOR BLOWER WAS REDESIGNED, REDUCING THE POWER REQUIRED TO DRIVE IT
40. TM BLOWER PERFORMANCE	BY 28%

41. 1982 SUMMARY

THE 1982 GAINS WERE THE BEST YET, 3.9% SAVINGS FROM 1978 LEVEL, THE MAJOR CONTRIBUTOR BEING THE FIRE RING PISTON.

42. 1982 SUMMARY BAR CHART

WE ARE NOW DOWN TO 92.9% OF THE 1978 LEVEL.

43. 1983 IMPROVEMENTS

THE 1983 CHANGES RESULT IN EVEN GREATER GAINS.

44. LOW IDLE 200 RPM

THE ENGINE IDLE SPEED IS AGAIN LOWERED, NOW TO 200 RPM REDUCING THE FUEL CONSUMED WHILE IN THIS MODE TO 61% OF THAT CONSUMED WHEN IDLING AT 315 RPM. IT HAS BEEN NECESSARY TO PROVIDE OVERRIDING TEMPERATURE SENSITIVE CONTROLS TO KEEP THE ENGINE TEMPERATURE UP AND DEVELOP A SPECIAL HIGH OUTPUT AUXILLIARY GENERATOR TO KEEP THE BATTERIES CHARGES AT LOW IDLE SPEEDS. THE ANNUAL SAVINGS DUE TO LOW IDLE OPERATION HOWEVER CAN EXCEED 6,000 GALLONS PER LOCOMOTIVE.

45. 2 SPEED D.B. (200 RPM)	CORRESPONDINGLY THE LOW SPEED DYNAMIC BRAKE OPERATION IS REDUCED TO 200 RPM.
46. 2 SPEED, 4 BLADE FANS	THE ENGINE COOLING SYSTEM FANS WERE AGAIN REDESIGNED, REDUCING THE NUMBER OF BLADES PER FAN FROM 6 TO 4 AND INTRODUCING A HALF SPEED MODE OF OPERATION.
47. RADIATOR COOLING SYSTEM	AS THE RADIATOR SURFACE AREA WAS INCREASED AND THE NUMBER OF BLADES PER FAN WERE DECREASED FROM 9 TO 6 TO 4, AND FINALLY THE LOW SPEED OPERATION WAS INTRODUCED, THE NOMINAL POWER REQUIREMENTS WERE REDUCED BY NEARLY 60%.
48. DUAL SPEED FANS	THIS ILLUSTRATES THE POWER ADVANTAGE OF THE 2 SPEED OPERATION. FOR INSTANCE 3 FANS AT ½ SPEED PASS MORE AIR THROUGH THE RADIATORS WHILE CONSUMING LESS POWER THAN ONE FAN AT FULL SPEED.

49. EC ENGINE	NOW THE BIG CHANGE FOR 1983. OUR TURBO CHARGED ENGINES HAVE ALWAYS OPERATED AT 14.5:1 COMPRESSION RATIO
50. 16:1 PISTON	AFTER A LONG SERIES OF DEVELOPMENTS IN ENGINE COMPONENTS BOTH OPERATIONALLY AND DURABILITY WISE, THE 16:1 COMPRESSION RATIO PISTON HAS BEEN RELEASED.
51. F3A TURBO	ALONG WITH THE F3A TURBO CHARGER AS USED ON OUR HIGHER HP ENGINES, WITH MORE RUGGED COMPONENTS AND MORE EFFICIENT COMPRESSOR IMPELLOR AND DIFFUSER.
52. 1983 SUMMARY LIST	THE 1983 GAINS, INCLUDING THE 200 RPM IDLE AND D.B. SPEED, THE 2 SPEED, 4 BLADE COOLING FANS, THE 16:1 COMPRESSION RATIO ENGINE WITH THE F3A TURBO CHARGER, ADD UP TO A 4.6% REDUCTION IN FUEL CONSUMED ON THE MEDIUM DUTY CYCLE.

53. 1983 SUMMARY CHART

NOW OUR ANNUAL CONSUMPTION IS DOWN TO 88.3% OF THE 1978 RATE.

54. 1978-83 SUMMARY

SUMMARIZING THE IMPROVEMENTS ON THE MEDIUM DUTY CYCLE FOR 1979 WERE 1.8% 1980 .3%, 1981 1.1%, 1982 3.9%, 1983 4.6%. FOR A TOTAL OF 11.7% OR 39,546 GALLONS PER LOCOMOTIVE PER YEAR.

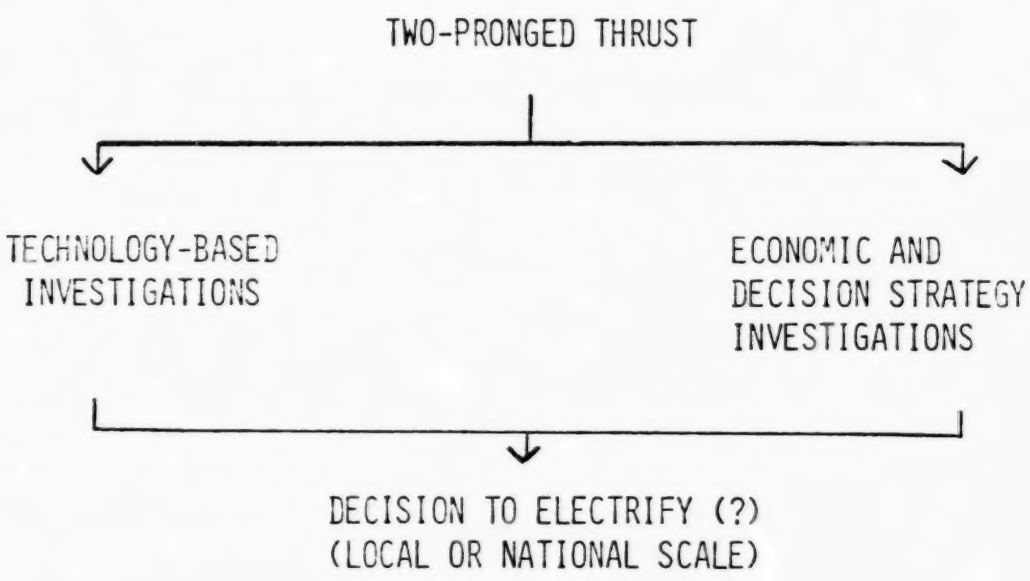
55. GM LOGO

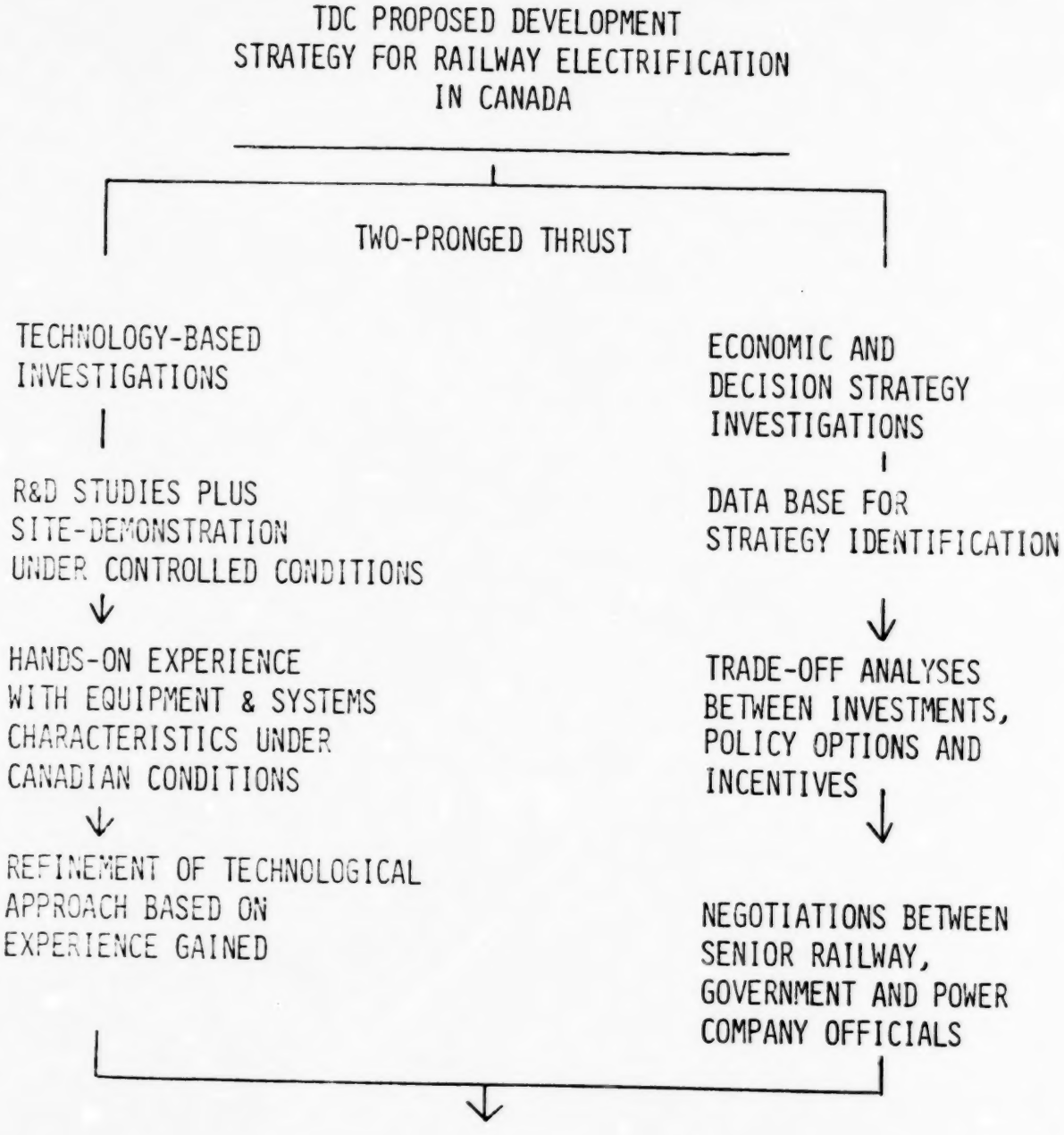
MOST OF THESE CHANGES ARE RETROFITABLE TO OLDER LOCOMOTIVES. WHILE THESE DEVELOPMENTS WERE TAKING PLACE, PARALLEL DEVELOPMENTS WERE IN PROCESS ON OUR HIGHER HP "F" SERIES ENGINES. RESEARCH AND DEVELOPMENT CONTINUES WITH GOOD PROMISE OF ADDITIONAL MAJOR FUEL SAVINGS WITHOUT JEOPARDIZING DURABILITY OR MAINTAINABILITY OF OUR LOCOMOTIVES.

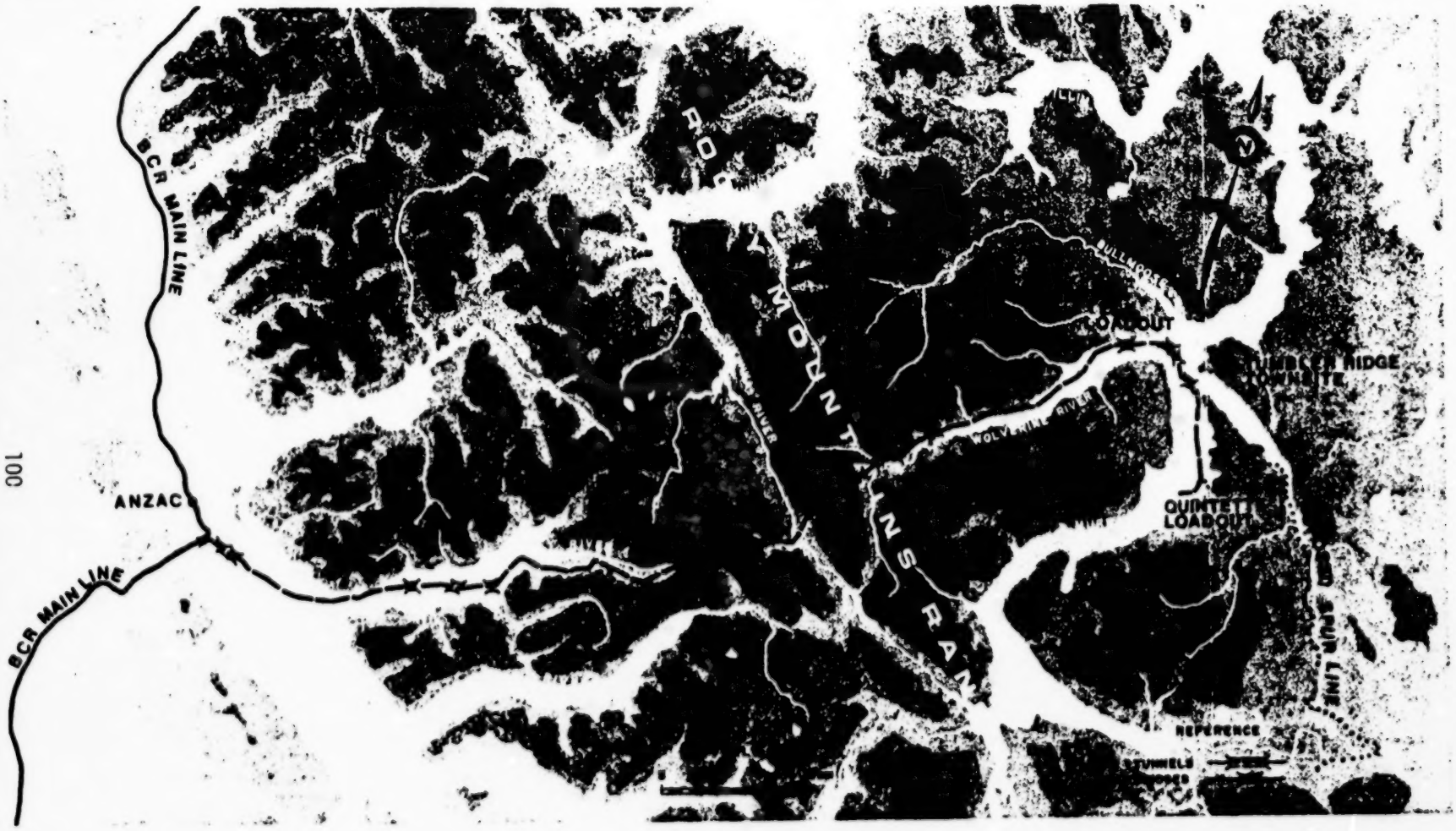
RAILWAY ELECTRIFICATION

C. Alfred Versailles
Senior Development Officer
Transportation Development Centre

TDC PROPOSED DEVELOPMENT
STRATEGY FOR RAILWAY ELECTRIFICATION
IN CANADA




TDC PROPOSED DEVELOPMENT
STRATEGY FOR RAILWAY ELECTRIFICATION
IN CANADA
TWO-PRONGED THRUST
TECHNOLOGY-BASED
INVESTIGATIONS
R&D STUDIES PLUS
SITE-DEMONSTRATION
UNDER CONTROLLED CONDITIONS
HANDS-ON EXPERIENCE
WITH EQUIPMENT & SYSTEMS
CHARACTERISTICS UNDER
CANADIAN CONDITIONS
REFINEMENT OF TECHNOLOGICAL
APPROACH BASED ON
EXPERIENCE GAINED
ECONOMIC AND
DECISION STRATEGY
INVESTIGATIONS
DATA BASE FOR
STRATEGY IDENTIFICATION
TRADE-OFF ANALYSES
BETWEEN INVESTMENTS,
POLICY OPTIONS AND
INCENTIVES
NEGOTIATIONS BETWEEN
SENIOR RAILWAY,
GOVERNMENT AND POWER
COMPANY OFFICIALS
DECISION TO ELECTRIFY (?)
(LOCAL OR NATIONAL SCALE)



TUMBLER RIDGE BRANCH LINE CONSTRUCTION

RAILWAY ELECTRIFICATION

DEMONSTRATION ON THE BRITISH COLUMBIA RAILWAY

TUMBLER RIDGE BRANCH LINE DESCRIPTION

1. TUMBLER RIDGE BRANCH LINE FROM ANZAC INTO NORTHEAST COAL DEVELOPMENT - 132 ROUTE KM ELECTRIFIED

2. ANZAC IS 130 KM NORTH OF PRINCE GEORGE

3. MAXIMUM GRADIENT - 1.2% COMPENSATED - LOADED DIRECTION
   - 1.5% COMPENSATED - EMPTY DIRECTION

   MAXIMUM DEGREE OF CURVATURE -6^{o}

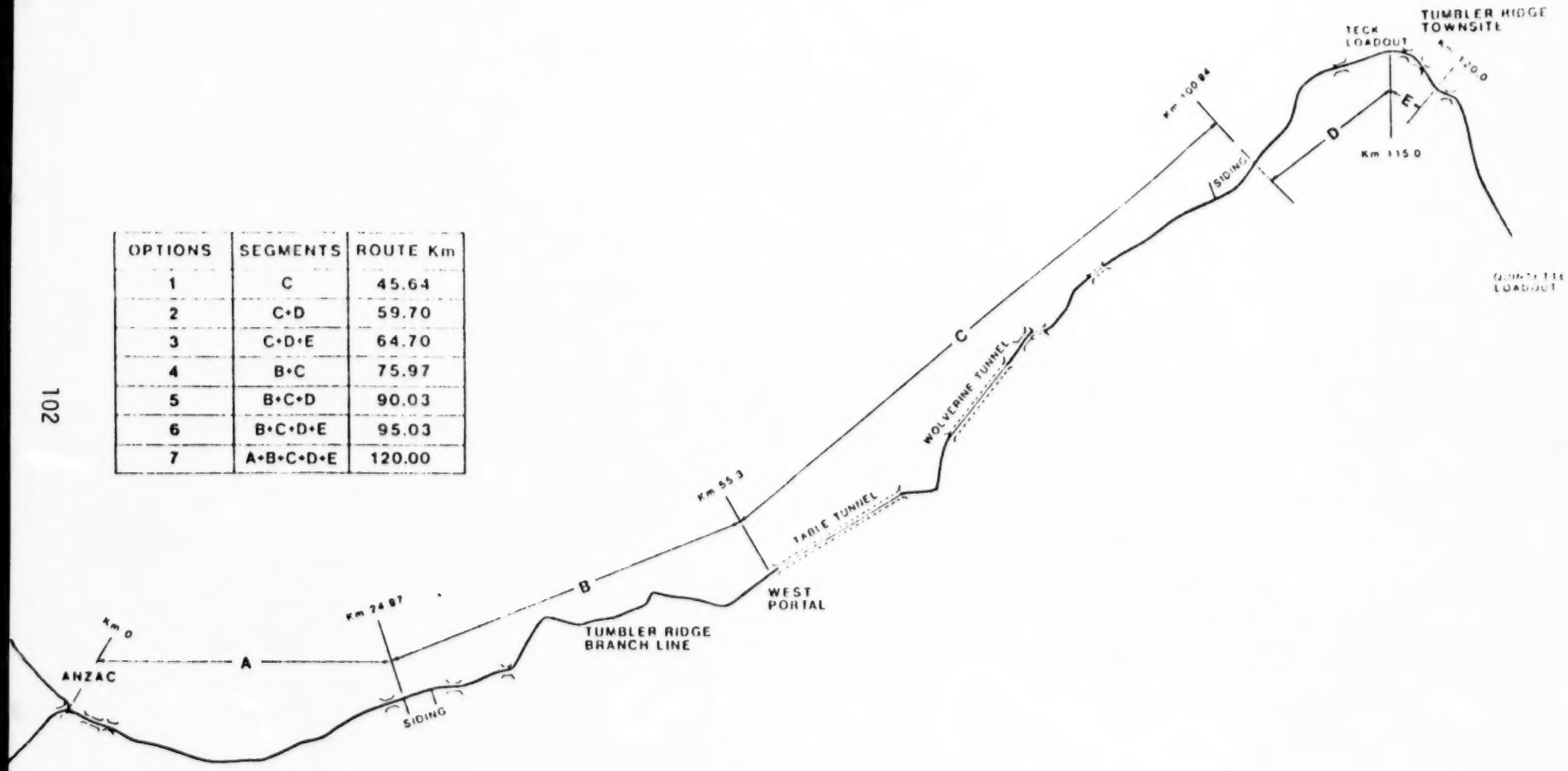
4. TWO LONG TUNNELS - TABLE TUNNEL : 9.1 KM
   - WOLVERINE TUNNEL: 6.0 KM

5. SIDINGS INSTALLED NEAR KM 25, 55, 80 AND 100 WITH LOADOUT LOOP TRACKS NEAR KM 115 AND 132

6. TRACK SPEED - 56 KM PER HOUR
   - 32 KM PER HOUR WESTWARD LEAVING TABLE TUNNEL

ELECTRIFICATION OPTIONS
TUMBLER RIDGE BRANCH LINE

OPTIONS	SEGMENTS	ROUTE Km
1	C	45.64
2	C+D	59.70
3	C+D+E	64.70
4	B+C	75.97
5	B+C+D	90.03
6	B+C+D+E	95.03
7	A+B+C+D+E	120.00



BCR DEMO

ENERGY CONSUMPTION AND COSTS COMPARISON

	OPERATION	
	ELECTRIC	DIESEL
FUEL USED PER YEAR	35,261,000 KWH	1,958,000 GAL.
FUEL IN EQUIVALENT UNITS	127,000 GJ	343,000 GJ
ANNUAL COST OF FUEL ($1982)	$1,715,000	$2,445,000
ELECTRIC OPERATION	REDUCTION OF 63% (GJ)	
DIESEL LOCOMOTIVES	27% THERMO-MECHANICAL EFF.	
ELECTRIC LOCOMOTIVES	76% ELECTRO-MECHANICAL EFF.	

RAILWAY ELECTRIFICATION

DEMONSTRATION ON THE BRITISH COLUMBIA RAILWAY

CAPITAL COST DIFFERENTIAL

1.	DIESEL-ELECTRIC OPERATION	
	1.1 TUNNEL VENTILATION	$19.5M
	1.2 DIESEL-ELECTRICS	$23.3M
	TOTAL	$42.8M
2.	ELECTRIC OPERATION	
	1.1 POWER SUPPLY AND CATENARY	$28.4M
	1.2 ELECTRICS	$28.6M
	TOTAL	$57.0M
3.	DIFFERENTIAL COST	$14.2M

RAILWAY ELECTRIFICATION

DEMONSTRATION ON THE BRITISH COLUMBIA RAILWAY

FUNDING BREAKDOWN

- BC RAIL		$47.0M
- BC GOVERNMENT		$ 5.0M
- FEDERAL GOVERNMENT		$ 5.0M
- EMR	$2.5M	
- IT&C	$0.5M	
- TC	$2.0M	
TOTAL COST		$57.0M

RAILWAY ELECTRIFICATION

DEMONSTRATION ON THE BRITISH COLUMBIA RAILWAY

R & D PROJECTS

ITEM	DESCRIPTION	ESTIMATED COST ($000)
1.	DATA GATHERING, EXPERIENCE MONITORING, ANALYSIS AND REPORTING	$ 500
2.	50 KV OCS DESIGN AND SOURCING	$ 200
3.	SUBSTATION DESIGN AND SOURCING	$ 300
4.	LOCOMOTIVES TESTING AND EVALUATION	$ 300
5.	FIELD EVALUATION OF CATENARY	$ 500
6.	MAINTENANCE PROCEDURES AND RECOMMENDED STANDARDS	$ 100
7.	LICS INTEGRATION AND EVALUATION	$ 100
	TOTAL ESTIMATED COST.....	$2,000

RAILWAY ELECTRIFICATION

DEMONSTRATION ON THE BRITISH COLUMBIA RAILWAY

TUMBLER RIDGE BRANCH LINE ELECTRIC OPERATION

1. UNIT COAL TRAINS BETWEEN NORTHEAST B.C. MINES AND PRINCE RUPERT

2. UNIT TRAIN CONSIST
   - 4 ELECTRIC LOCOMOTIVES
   - 98 COAL CARS (12,920 TONS)
   - 1 CABOOSE

3. TRAIN CREWS
   - MINE SITE TO PRINCE GEORGE: BCR
   - PRINCE GEORGE TO PRINCE RUPERT:CN RAIL

4. TUNNEL VENTILATION - NONE REQUIRED

NOTE: NON ELECTRIFIED OPERATION WOULD REQUIRE EXTENSIVE TUNNEL VENTILATION BECAUSE THREE DIESEL-ELECTRIC LEAD LOCOMOTIVES PLUS THREE DIESEL-ELECTRIC PUSHER LOCOMOTIVES WOULD BE REQUIRED

TRBL ELECTRIFICATION

OVERVIEW

- CONSTRUCTION AND ELECTRIFICATION TO BE COMPLETED BY DECEMBER 1983

- POWER PROVIDED BY A B.C. HYDRO TRANSMISSION LINE BEING BUILT FROM W.A.C. BENNETT DAM TO COAL FIELD TOWNSITE OF TUMBLER RIDGE

- TRACTION SUBSTATION TO BE BUILT ADJACENT TO TOWNSITE MAIN SUBSTATION

- 50 kV, 60 Hz POWER FEED SYSTEM (THIRD IN THE WORLD) WITH ONE SERIES CAPACITOR STATION AND PARALLEL FEEDER AND GROUND WIRES

- SEVEN 6,000 HP SIX-AXLE ELECTRIC LOCOMOTIVES TO BE SUPPLIED BY GM CANADA LTD, DIESEL DIVISION, LONDON, ONTARIO

TRBL ELECTRIFICATION

SYNOPSIS OF PROGRESS

01-01-83

- LOCOMOTIVES - ORDERED

- SUB-STATION

  - TRANSFORMERS - ORDERED
  - CIRCUIT BREAKERS - ORDERED
  - PROTECTION AND CONTROL EQUIPMENT - ORDERED
  - OTHER MAJOR EQUIPMENT - SUPPLIERS SELECTED
  - CIVIL AND ARCHITECTURAL DESIGN - IN PROGRESS

  (ALL POWER-ASSOCIATED CONTRACTS TO BE AWARDED BEFORE END OF MARCH 1983)

- OCS

  - DESIGN AND SPECIFICATIONS OF EQUIPMENT - COMPLETE
  - TENDERS CALLED FOR: POLES
    : INSULATORS
    : CAST IRON HARDWARE
  - FOUNDATION DESIGNS - COMPLETE
  - PREPARATION OF INSTALLATION SPECIFICATIONS - IN PROGRESS

LEGEND

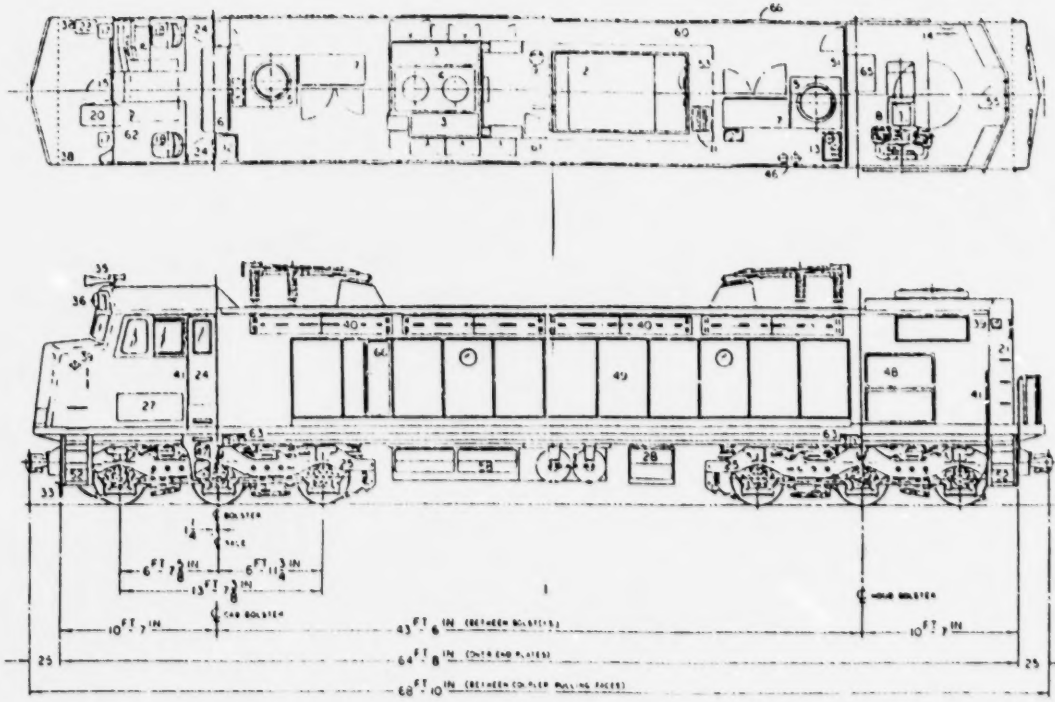
1. PANTOGRAPH (TRIPLE SINGLE TYPE)
2. MAIN TRANSFORMER (PROPULSION RATING)
3. THYRISTOR CONVERTER CABINET
4. OIL COOLER BLOWER
5. TRACTION MOTOR BLOWER ASSEMBLY (2 TOTAL)
6. ELECTRICAL CONTROL CABINET
7. CONTACTOR CABINET
8. AIR COMPRESSOR (TWIN) (1 / MOTOR 150 H.P. - 3600 RPM @ 900 RPM)
9. AIR RESERVOIR
10. MAIN AIR BRAKE EQUIPMENT
11. AUXILIARY TRANSFORMER
12. REFRIGERANT/WATER CYCLER
13. AUXILIARY COMPRESSOR & AIR DRYER UNIT
14. HEADLIGHT
15. SHORT HOOD ACCESS
16. DRIVER'S CONSOLE
17. CAB HEATERS
18. CAB SEATS
19. SERVICE TRANSFORMER
*20. RADIO EQUIPMENT
21. ENGINE
*22. EQUIPMENT BOX FOR SPEED DETECTOR & INDICATOR
23. CAB WINDSHIELDS
24. CAB DOOR
25. TRUCK (2 AXLE - A1C TYPE)
26. WHEELS (42 IN. DIA.)
*27. AIR BRAKE EQUIPMENT ACCESS
28. BATTERY BOX (2/3 NTD.)
29. TRACTION MOTOR AXLE (2 TOTAL)
30. MAIN RESERVOIR (2/3 NTD.)
31. COUPLER (E TYPE)
32. DRAFT GEAR (MC TYPE)
33. PILOT
34. MARKER BOX
35. HORN
36. HEADLIGHT
37. CLASSIFICATION LIGHTS
38. SANDBOXES (20 & 40 FT /MIN MAXIMUM)
39. SANDBOX FILLERS
40. AIR INLETS
41. HANDRAILS
*42. DYNAMIC BRAKE FAN (50 HP, DIA.)
*43. DYNAMIC BRAKE GRIDS (RADIAL TYPE)
44. EQUIPMENT REMOVAL NOTCHES
45. THYRISTOR CONTROL COMPARTMENT & MAIN TRANSFORMER REMOVAL HATCH

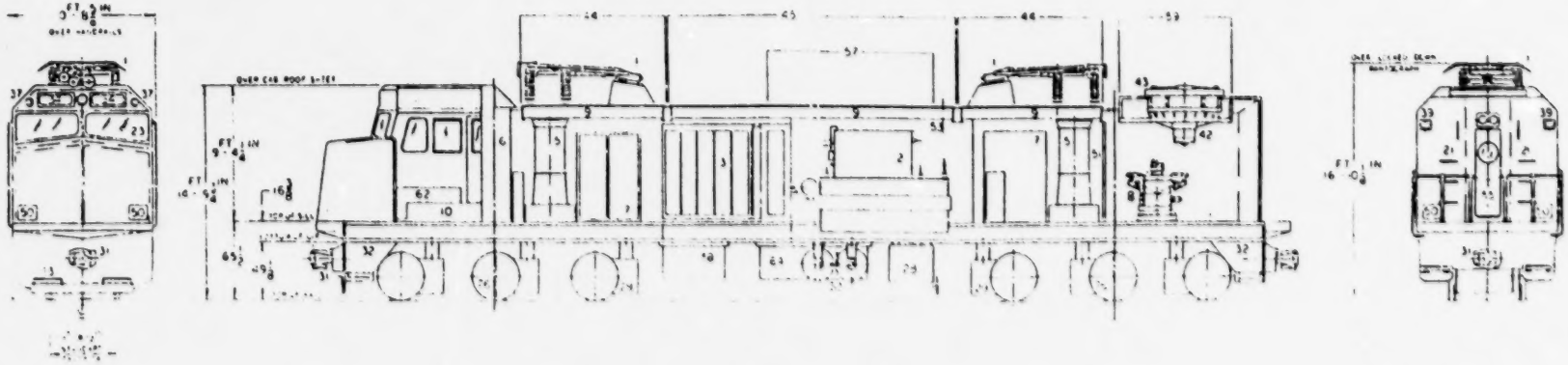
LEGEND (CONTINUED)

46. FIRE EXTINGUISHER (AUTOMATIC)
47. GRADE AID STEP
48. AIR INLET FOR COMPRESSOR & DYNAMIC BRAKE FAN
49. 5 OF PANT 5 CANTILEVER TYPE STRUCTURE
50. SAND TRAP ACCESS
51. RADIATOR ROOM PARTITION
52. STEPS
53. HIGH VOLTAGE BUSHING
54. CONTROL CABINET (NOT SHOWN)
55. LONG HOOD ACCESS
56. RADIATOR ROOM VENTILATOR MOTOR & BLOWER SYSTEM (NOT SHOWN)
57. AREA RESERVED FOR HIGH VOLTAGE EQUIPMENT
- MAIN CIRCUIT BREAKER
- POTENTIAL TRANSFORMER
- LIGHTING ARRESTORS
- HIGH VOLTAGE BUSHING
*58. CAPACITOR BOX (2/3 NTD.)
*59. DYNAMIC BRAKE GRID
60. CONDENSER
61. HIGH VOLTAGE ACCESS DOOR
62. SEATING PLATFORM
63. JUNCTION POST
*64. FILTER BLOCK BOX (2/3 NTD.)
65. DYNAMIC BRAKE CONTACTOR CABINET
66. REFRIGERANT DOOR (2)

* MODIFICATION

NOTES
LOCOMOTIVE WEIGHT TOLERANCE = ± 3 1/2 %
LOCOMOTIVE WIDTH TOLERANCE = ± 1/2 IN
TRUCK LATERAL AT BOLSTERS = ± 1/4 IN. MAX
LOCOMOTIVE IS SHOWN IN WEIGHTED STANDING STILL ON LEVEL AND TANGENT TRACK
ALL DIMENSIONS SHOWN IN PARENTHESES ARE MILLIMETER EQUIVALENTS





GF6C ELECTRIC LOCOMOTIVE

Significant Features:

Unit Rating

1. Nominal 3800 KW at the rail (5,300 HP approximately)

2. Power level can be "stepped" at 2600 KW - 3200 KW - 3800 KW with a final "top change" option to provide 4400 KW at rail (6000 HP).

Locomotive Weight

1. 178 Tonnes (392,000 lbs.) fully loaded.

2. 65,300 lbs. per axle.

Continuous Rating

1. Tractive effort is 400 KN (Kilonewton) at 34.5 Km/h. Approximately 90,000 lbs. This is the continuous rating of the Traction Motors.

2. Dynamic Braking of 3500 KW absorption, at rail.

Main Circuits

1. Single 50 KV - 60 HZ overhead catenary.

2. Dual Pantographs (choice of make under study).

3. Main Transformer and Auxiliary Power supplies, with Thyristor controlled Rectifiers.

4. Traction Motors with separately excited Fields.

General Arrangement

1. A nose door will be installed, probably left of centre of cab.

2. Console type cab is being designed.

3. Compact operating controls with electric interlocking will be incorporated.

4. "WABCO" style 30 CDW brake valve, modified for Freight use is specified.

5. Full width body style.

THE FEDERAL ENERGY R & D PROGRAM

Dr. W. F. Johnson
Chief, Energy
Research & Development
Transport Canada

Good afternoon gentlemen.

My presentation this afternoon is to acquaint you with the actities of the Federal Energy R&D Program and in particular those parts of the program managed by Transport Canada. I am well aware that many of you are already acquainted with this program. However, others of you are not so well informed of the activities of the Federal Energy R&D Program and this is my opportunity to give a commercial if you like for TC's participation in this program.

FEDERAL ENERGY R&D PROGRAM

First let me describe the scope and scale of the Federal Energy R&D Program. The Federal Program is interdepartmental and includes EMR, TC, NRC, DND and ITC. It is coordinated by an Interdepartmental Panel on energy research and development. The Panel is responsible for developing and implementing measures to ensure that the objectives and activities of the federal program support the attainment of national energy policy goals and objectives. The Panel is chaired by Energy, Mines and Resources which also provides secretariat services through the Office of Energy R&D. The program is divided into six tasks of which three are of direct interest to the transportation sector including the rail mode. These tasks are Conservation, New Liquid Fuels and Conventional Oil and Gas. Each task is headed by a Task Coordinator who is responsible for recommending the objectives and priorities for his task.

The Conservation task has for its main objective to increase the energy efficienty in the various economic sectors including transportation.

The New Liquid Fuels task has for its objective to develop economic, timely and environmentally safe fuels and especially liquid fuels for the transportation sector.

The Conventional Oil and Gas task has for its objective the development of conventional oil and gas in frontier regions and from the traditional resource areas in other parts of Canada. This task includes the transportation of new energy commodities and the transport of hazardous fuels with a strong emphasis on the rail mode.

The Federal Energy R&D Program is large by R&D standards. The total budget for 1983/84 is over $150,000,000.00 of which $18,000,000.00 are for transportation related activities. Of this Transport Canada will receive over $10,000,000.00 for activities managed by this department.

The significance of the Federal Energy R&D Program is that it is well funded, linked to a government priority issue, coordinated across departments to minimize duplication and maximize effectiveness and spans all aspects from energy production through to end-use.

TC PARTICIPATION

Transport Canada participates in the Federal Energy R&D Program in all aspects of its activities. TC prepares strategic plans for transport-related elements of the program. It participates in program planning for future years to negotiate program objectives and resource levels. TC participates in project selection. TC is responsible for the management of research contracts. TC is an agent to ensure technology transfer of research results to industry. In this regard, it is worth noting that within the Conservation Task there is an Industry Energy R&D Program which can facilitate industrial innovation related to energy objectives. As well, outside of the federal energy R&D program is the Federal/Provincial Conservation and Renewable Energy Demonstration Program or CREDA for short, which can be used to fund demonstrations of new technology.

TC PROGRAM ORGANIZATION

The TC Energy R&D Program is organized to permit the entire department to contribute to program objectives and receive support for related R&D. The program is coordinated centrally by the Research Planning and Coordination Branch and projects are managed decentrally by R&D proponents in the Administrations and in TDC. This two part organizational structure permits Transport Canada to formulate integrated departmental plans in light of overall government objectives and priorities for energy as well to formulate departmental R&D activities which reflect its mandate, R&D requirements and opportunities.

TC ENERGY R&D PROGRAM PRIORITIES

Among the transport modes, the road mode receives first priority and the greatest attention and support. However, the other modes are not neglected and the rail mode has received significant and growing resource allocations.

TC ENERGY R&D PROGRAM SUPPORT FOR RAIL RELATED R&D IN 82/83

Under the Conservation Program, which aims to increase fuel efficiency in the rail mode and to investigate rail electrification under Canadian conditions, a total of $320,000 has been allocated.

Under the New Liquid Fuel Use Program, which aims to develop timely, economic and safe alternatives to conventional oil base fuels for railway application, a total of $150,000 has been allocated.

Under the Transport of Hazardous Commodities Program which aims to develop timely, economic and safe alternatives to transport of hazardous fuels by rail, a total of $300,000 has been allocated.

In addition to these R&D funds, additional resources have been made available from the CREDA program for the BCR rail electrification demonstration amounting to $2.5 million over three years.

These resources total over one and a half million dollars per year over a three year period. Obviously, the Federal Energy R&D Program is an important source of funding support for railway related R&D in Canada. Our task in Transport Canada is to use these resources wisely not only to meet Federal energy objectives but also to meet the many pressing energy related problems in the railway sector.

In order to better define our objectives and priorities for the rail mode, the Research Planning and Coordination Branch is now preparing a strategic rail energy R&D plan. This plan will assemble available information on alternative railway engine/fuel options covering the entire range from incremental adaptations through to radical system changes. These options will be analyzed and compared to the baseline diesel/electric locomotive case in terms of fuel price and availability scenarios, technological feasibility, overall economics, and safety and environmental factors. The aim of this research is to arrive at an objective rank ordering of energy-related options for railway propulsion in Canada in the short, medium and long terms. This plan will document our collective knowledge in TC and the industry to enable us to present a stronger case for assigning greater priority to the rail mode and to increase resource allocation for energy related R&D. This work is now underway and involves ourselves, TDC and the Surface Administration. In the near future, we plan to seek industry views and comments.

PARTICIPATION BY TRANSPORT SECTOR

I would like to conclude my remarks this afternoon with an invitation to the Transport Sector and in particular the rail transport industry to participate in accomplishing the goals of this program. I suggest there are three ways in which this participation can take place: the first is through existing sub-program activities directed by TDC, for example, rail electrification studies, the second is through a response to TC's general request for proposals published in the January issue of the Supply and Services Bulletin which solicits proposals related to energy conservation in the railway sector. This RFP continues open until March 31, 1983. The third is through applications to the Industry Energy R&D Program sponsored by

the Department of Insutry, Trade and Commerce.

Thank you.

DISCUSSION

DISCUSSION

Following presentation of the final paper, Mr. Eggleton advised that Mr. R. W. Radford, Chief Electrical and Mechanical Engineer for CN Rail, had agreed to make a few remarks concerning his recent studies of fuel consumption of freight trains hauled by diesel electric locomotives.

Mr. Radford explained briefly that the work had been carried out using a simulation program developed to examine the effect on fuel consumption of changes to a number of parameters of freight train operation. These included train consist, car weight, gradient, average speed, meet strategy, throttle control, locomotive axle arrangement and train marshalling. His findings showed that a reduction to subdivision speed and/or average speed, and the substitution of other methods of train control for power braking are the two easiest and most effective ways to reduce fuel consumption.

Mr. Radford will be presenting a paper on his investigations at the Joint ASME/IEEE Railroad Transportation Conference in Baltimore, Md., April 26-28, 1983.

At the conclusion of Mr. Radford's remarks the Chairman opened the floor for questions. Following is a summary of the discussions that took place.

Computer aided dispatching:

A delegate noted that the Location, Identification and Control System (LICS), under development by Glenayre Electronics of Vancouver for the past several years, with the assistance of TDC and BC Rail, could perhaps be overlaid on an existing railway signal system to provide information on train

location to the Despatcher. This would enable him to ascertain if speed reductions to other trains would be appropriate to avoid stops at planned meet points, a technique touched on by Bill Cyr earlier in the day, in order to reduce fuel consumption. It was concluded that the LICS system could no doubt be used in that way, but that other systems would also provide the same benefit.

Type of Fuel

A delegate questioned whether anything is being done to relate refinery output to the most "desirable" fuel for railway locomotives. In response, it was pointed out that any attempts to predict the most "desirable" fuel must recognize the changing nature of the crude oil supply and the consequent effect on refinery output. A decision to reduce the percentage of heavy ends would have a similar effect. It is therefore better, at least theoretically, to have a more fuel tolerant engine, than to (perhaps) retrofit all existing engines to burn a certain currently economical available fuel, the continued production of which cannot be assured. During this discussion, it was noted by Mr. Cyr that very approximately, the cost of railway diesel locomotive engine maintenance today is $1 per mile, whereas the cost of engine fuel is $3 to $4 per mile.

Engine Design

The matter of additional engine changes to further reduce fuel consumption was also discussed. Whilst the manufacturers' representatives felt these will indeed occur, the gains will not come quickly and, most likely, the complexity of the changes will increase with consequent increased difficulty and cost to achieve equivalent savings in existing engines by

retrofitting. On the question of staged, or pilot, fuel injection in order to broaden the receptivity of the engine, it was stated that although technically feasible, it gets very complicated. The choice is between a very complex single injector and the addition of a second injector. In the latter case, unless the injector is electonically actuated, an additional cam shaft is required.

Research and Development

The railway operators see ways and means to burn a fuel mixture containing up to 30 percent heavy ends as a very high R & D priority. This would benefit the petroleum industry by broadening the market for a currently low demand product, and would reduce the railways' fuel cost. Currently, the cost to CN for locomotive fuel is in the order of $400 million annually.

The development of an effective, low cost engine heater to enable shut down of engines at temperatures below freezing, is also high on the priority list.

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TDC RAILWAY ENERGY SEMINAR

March 15, 1983

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POOR

QUALITY

ORIGINAL